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FINAL REPORT

DEMONSTRATION OF SHOCK-ABSORBING CONCRETE (SACON) BULLET TRAP TECHNOLOGY

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13. ABSTRACT *(Maximum 200 words)*

The Environmental Security Technology Certification Program (ESTCP) funded a technology demonstration of shock-absorbing concrete (SACON) bullet-trapping technology. SACON is a low-density, fiber-reinforced, foamed concrete developed by the Waterways Experiment Station (WES). SACON offers significant benefits in comparison to current commercial off-the-shelf (COTS) bullet-trapping technologies. SACON provides Range Managers with a means of effectively capturing and containing lead on small-arms ranges without sacrificing training realism. Demonstration objectives focused on identifying and validating the performance, cost, safety, logistics, training realism, and recycling aspects of the SACON bullet-trapping material. SACON bullet traps tested in a 25-Meter Range application contained 87 percent of the bullets fired at the trap. Exposure of the bullet debris to the SACON material and weathering resulted in the formation of insoluble lead corrosion products and the generation of nonhazardous waste products. The application of SACON reduced localized soil erosion typically found in the vicinity of target emplacements. Ricochet testing results indicated bullet impacts were within the surface danger zones (SDZs) for the range types chosen for the demonstration. A nonrecurring cost of approximately $1600 per lane and an annual recurring cost of $3800 per lane were estimated to outfit a 20-lane 25-Meter Range with SACON bullet traps.

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EXECUTIVE SUMMARY

Small-arms training is a requirement in all branches of the military. Over 1800 active military outdoor small-arms training ranges are operated in the United States. In a typical year, small-arms training activities consume over 300 million rounds and add between 1 and 2 million pounds of lead to the ranges in the form of bullet debris. As a result, Department of Defense (DOD) small-arms ranges accumulate significant amounts of lead in the soil. Because elevated levels of lead in groundwater and soils can present a health hazard, the migration of heavy metals can result in environmental regulators imposing training restrictions, which ultimately will reduce operational readiness. Technology to reduce lead contamination is recognized as a high-priority DOD user requirement. The Environmental Security Technology Certification Program (ESTCP) funded a technology demonstration of shock-absorbing concrete (SACON) bullet-trapping technology to address this requirement.

SACON is a low-density, fiber-reinforced, foamed concrete developed by the Waterways Experiment Station (WES) to be used in the construction of live-fire training facilities such as hand-grenade houses and Military Operations in Urban Terrain (MOUT) villages. SACON was developed to minimize the hazard of ricochets during urban training. The shock-absorbing properties of the concrete necessary to reduce ricochets also function to create a medium for capturing small-arms bullets. In a properly designed SACON bullet trap, the incoming bullet buries itself in the concrete. The alkaline nature of the concrete results in the creation of less-soluble lead corrosion products, which reduces the leaching of lead into the surrounding soil. The use of SACON on small-arms ranges provides the DOD with a recyclable bullet-trap material that does not detract from training realism.

Demonstration objectives focused on identifying and validating the performance, cost, safety, logistics, training realism, and recycling aspects of the SACON bullet-trap material. Field demonstration of SACON was conducted at the United States Military Academy (USMA) in West Point, New York, from April through November 1997 and at Fort Knox, Kentucky, from March 1997 through January 1998. SACON recycling was demonstrated at WES in October 1997. Accelerated durability and ricochet testing was conducted at the U.S. Army Aberdeen Test Center (ATC) in March 1998.

The lead containment efficiency of SACON was determined through data collected during durability testing conducted at ATC. SACON bullet traps tested in a 25-Meter Range application contained 87 percent of the bullets fired at the trap. The majority of the released fraction of bullet debris was deposited immediately in front of the trap, forming a debris pile. Lead concentrations in the trap and debris pile exceeded 60,000 mg/kg. In the absence of weathering, the samples exhibited Toxicity Characteristic Leaching Procedure (TCLP) levels that exceeded 5 mg/L, which would result in a hazardous waste classification based on lead toxicity. However, all samples taken from SACON bullet traps tested at Fort Knox and USMA that were exposed to the effects of weathering exhibited TCLP levels of less than 5 mg/L. Exposure of the bullet debris to the SACON material resulted in the formation of insoluble lead corrosion products. As a result, all SACON debris removed from these ranges was classified as nonhazardous and disposed of as a solid waste.

Soil erosion resulting from repeated bullet impacts was reduced in front of and behind the target emplacements by burying SACON in these areas. Reducing soil erosion aids in mitigating the physical transport of lead debris from the bullet's impact point on the range. SACON also provides adequate protection of the target coffin when properly maintained. Mitigation of this impact erosion results in less-frequent maintenance requirements in these areas. An estimate of a two-thirds reduction in maintenance time for these areas was subjectively made based on visual observations during the demonstrations.

The cost of installing and using SACON was estimated based on the costs incurred during the conduct of the demonstration and the application of these costs to SACON's potential use on a 20-lane 25-Meter Range. Nonrecurring costs associated with the SACON technology are incurred during the manufacturing, site evaluation, site preparation, and installation processes. Manufacturing costs were derived from a 10-yd^3 batch production rate of 90 lb/ft^3, polypropylene-fiber SACON. This mode of production corresponds to the mixing capacity of a modern transit mixer truck. A nonrecurring cost of approximately $1600 per lane was estimated to outfit a 20-lane 25-Meter Range with SACON bullet traps. The annual recurring costs associated with the use of SACON consist of maintenance, waste management, and replacement SACON block manufacturing. Recurring costs were derived based upon the assumption of an annual throughput of 600,000 M855 bullets on a 20-lane, 25-Meter Range and the durability of the SACON bullet-trap designs that were tested. The durability data generated during the demonstration were used to estimate the number of maintenance events that must be conducted annually to maintain the SACON bullet trap. Accelerated durability testing conducted at ATC indicated that a maintenance event will be required after 7,100 rounds are fired into the trap design that was tested. The 600,000-round annual throughput equates to 30,000 rounds fired at a single target on each lane. Based on the measured durability of the SACON bullet-trap design tested and its resultant maintenance frequency for the assumed 30,000 rounds per lane throughput, an annual recurring cost of $3800 per lane was estimated.

Ricochet testing was conducted at ATC to develop data to determine if SACON had any effect on the surface danger zone (SDZ) of the range. ATC measured the ricochet angles, velocities, and distances of two rifle and two pistol rounds after impacting a relatively flat SACON surface. The M855 and M193 rifle rounds were fired on 90-lb/ft^3 SACON blocks while the M882 and M1911 pistol rounds were fired on 70-lb/ft^3 SACON blocks. The Corps of Engineers Engineering Support Center, Huntsville, Alabama, used these data to assess the impact of using SACON bullet traps on the SDZ of the 25-Meter, Automated Record Fire, Automated Field Fire, and the Combat Pistol Qualification Course Ranges. The assessment was completed by plotting the termination points of the ricochet projectiles upon the appropriate SDZ as published in AR 385-64. All ricochets resultant from ATC's testing terminated within the respective SDZ.

The procedures employed during bullet-trap maintenance were evaluated from a personnel safety perspective. Bullets impacting SACON create debris consisting of SACON chunks, dust, bullet slugs, and bullet fragments. The dust contains both crushed SACON and lead particles. Personal protective equipment (PPE) will be required to perform maintenance on SACON barriers to limit lead and dust exposure. Also, the weight of the SACON blocks used in the demonstration exceeded established limits for personnel lifting and handling to perform maintenance. Alternate block designs that utilize mechanical lifting and handling equipment must be used to safely install and maintain SACON bullet traps.

A recycling demonstration conducted at WES resulted in the determination that SACON material that has been shot with the M855 5.56-mm round cannot be economically recycled using the process employed by WES. The process did not meet steel or lead reduction targets established for the demonstration. It should be noted that the applicability of these targets has since been questioned based on the field results of the live-fire testing conducted on the recycled SACON blocks. Further testing will be required to establish valid recycling performance criteria. The cost of recovering the aggregate from the used SACON blocks is approximately 100 times the cost of purchasing new aggregate material. Disposal of the used SACON as a solid waste coupled with the purchase of new aggregate material would be approximately 75 percent cheaper than recovering the aggregate material; therefore, recycling was not proven to be economically feasible.

SACON, when used in a backstop-type application, compares directly with commercial off-the-shelf (COTS) bullet traps and the traditional soil berm. Comparisons were based on bullet debris containment, airborne lead emissions, maintenance requirements and frequency, waste handling and disposal requirements, and cost. In general, SACON compared favorably with the COTS bullet traps and soil berm in all areas with the exception of cost. An annual net equivalent value was calculated for each of the technology alternatives. Three categories of range usage and three categories of lead transport risk were defined to aid in the comparison. As expected, on ranges that exhibit a low risk for lead transport, the soil berm provides the lowest-cost method of capturing rounds. However, as the risk of lead transport from the range increases (lead transport risk should be determined prior to implementing any form of corrective action), the use of bullet traps becomes economically feasible when compared to the prospect of periodically removing the lead from the soil. Due to maintenance frequency, the SACON bullet traps tested proved to have a higher cost than other commercially available traps.

SACON does provide Range Managers with a means of effectively capturing and containing lead on small-arms ranges. SACON offers significant benefits in comparison to current COTS technologies. It exhibits an ability to inhibit the leaching of lead corrosion products, resulting in a lead stabilization capability not demonstrated by the COTS bullet traps and soil berm. The waste generated from the normal range use of SACON was not hazardous by characteristics and can be disposed of as a solid waste. SACON is not flammable and can be formed in any shape, making it adaptable to more range applications than standard COTS technologies. However, like all bullet traps, SACON is an expensive means of mitigating the risk of lead transport from ranges and should only be considered as a last resort for keeping ranges environmentally compliant. Other methods of reducing lead transport risk should be investigated prior to installing any bullet-trap technology. New methods of stabilizing the lead on the range and mitigating physical lead transport in storm water runoff are being developed and may provide more cost-effective means of reducing lead transport risk and bioavailability.

Final Report

Demonstration of Shock-Absorbing Concrete (SACON) Bullet Trap Technology

Prepared By: U.S. Army Aberdeen Test Center

Prepared For: U.S. Army Environmental Center and U.S. Army Corps of Engineers (USACE) Waterways Experiment Station

August 1999

DEPARTMENT OF DEFENSE

UNITED STATES OF AMERICA

ESTCP

ENVIRONMENTAL SECURITY TECHNOLOGY CERTIFICATION PROGRAM

Demonstration of Shock-Absorbing Concrete (SACON) Bullet Trap Technology

U.S. Army Aberdeen Test Center

U.S. Army Environmental Center and U.S. Army Corps of Engineers (USACE) Waterways Experiment Station

May 1999

1. Introduction

1.1 Background Information

Small-arms training is a requirement in all branches of the military. Over 1800 military outdoor small-arms training ranges are maintained in the United States (ref 1). In a typical year, small-arms training activities consume over 300 million rounds and add between 1 and 2 million pounds of lead to the ranges in the form of bullet debris (ref 2). Military small-arms ammunition is typically fabricated with a full-jacketed bullet consisting of a copper alloy jacket over a hardened lead alloy (lead and antimony) slug and a steel core penetrator (ref 3) (fig. 1-1). Through normal training operations, Department of Defense (DOD) small-arms ranges accumulate significant amounts of lead and other metals in the soil.

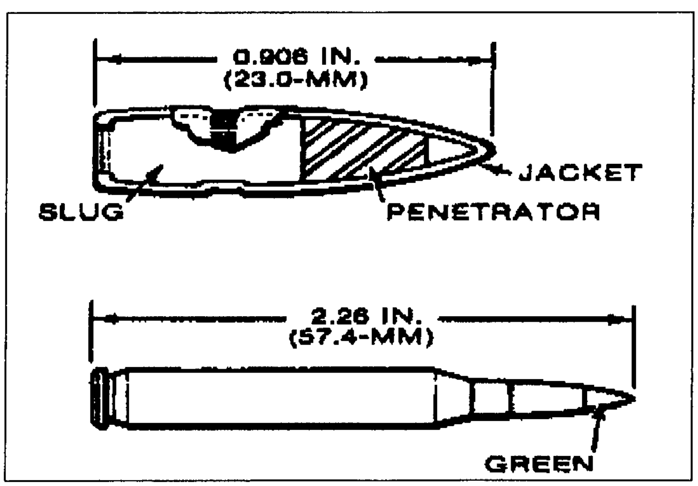


Figure 1-1. M855, 5.56-mm small-arms round.

Small-arms range debris consists primarily of intact bullets and bullet fragments. The lead in both intact bullets and bullet fragments will corrode. Important early corrosion products include lead oxides, lead hydroxides, and lead carbonates. Lead oxides, hydroxides, and carbonates are more soluble than the hardened lead alloy, making them more transportable (ref 1). These inorganic constituents may become mobile and migrate into groundwater or surface water. Because elevated levels of lead in groundwater and soil can present a health hazard, the migration of these heavy metals can result in environmental regulators imposing training restrictions which ultimately will reduce operational readiness.

Bullet traps function to capture bullets and offer a means to reduce the future deposition of bullet debris on small-arms ranges. By functioning effectively, bullet traps will prevent metals from being distributed in the range impact area and will allow for the removal of metals that would normally be distributed over the training range. Systems for trapping bullets before they enter the soil may provide significant cost avoidance when future range cleanup is required. Utilizing shock-absorbing concrete (SACON) bullet traps as an advanced "best-management practice" on at-risk ranges could enhance DOD's compliance with the proposed U.S. Environmental Protection Agency's (USEPA's) Military Munitions Rule (MR) through a reduction in the potential for off-site migration of lead, copper, and antimony.

Repeated bullet impacts break up the compacted soil around range targets and increase the rate of soil erosion, promoting lead transport. Repeated bullet impacts remove vegetation and create incised beaten zones that mark the locations of the target and reduce training realism. The use of SACON bullet traps may reduce this local erosion and thus improve training realism and reduce maintenance and repair activities.

The U.S. Army Environmental Center (AEC) recently completed a study on the applicability of various bullet-trap technologies to typical Army small-arms ranges. The project resulted in the publication of a technical report titled *Bullet Trap Feasibility Assessment* (ref 4). This effort identified existing bullet-trap designs, developed criteria for evaluating the designs, assessed the feasibility of using the bullet traps in conjunction with training, and developed a *Bullet Trap User's Guide* (ref 5). Of the friction-type traps listed in the *Bullet Trap Feasibility Assessment*, only the SACON bullet-trapping medium developed by the U.S. Army Corps of Engineers (COE) Waterways Experiment Station (WES) was listed as potentially recyclable.

SACON is a generic term for a low-density, fiber-reinforced foamed concrete developed by WES to be used in the specialized construction of live-fire training facilities such as hand-grenade houses and Military Operations in Urban Terrain (MOUT) villages (ref 6). SACON was developed to minimize the hazard of ricochets during urban training. The shock-absorbing properties of the concrete necessary to reduce ricochets also function to create a medium for capturing small-arms bullets. In a properly designed target system, the incoming bullet buries itself in the concrete. SACON is about one-half as dense and one-third as strong as conventional concrete. The cellular structure of the SACON collapses as the bullet enters the concrete, and the fibers in the concrete reduce spalling. The low permeability and high alkalinity of the concrete create less soluble corrosion products, which reduces the corrosion and leaching of lead into the surrounding soil. Using SACON as a bullet-trapping medium enables the capture and containment of bullets and a segregation from the soil environment. The innovative use of SACON on small-arms ranges provides DOD a recyclable bullet-trap material which, when applied in certain range configurations, does not detract from training realism.

The economic benefits derived by using bullet traps are gained primarily by avoiding or lessening anticipated future remediation efforts at ranges that present medium to high risk for lead migration.

1.2 Official DOD Requirement Statement

Specific DOD user requirements addressed by this program are identified in Table 1-1. DOD uses soil berms as backstops at small-arms firing ranges. These berms become contaminated with lead and can potentially contaminate groundwater and complicate any effort to recycle lead and copper in the bullets.

TABLE 1-1. DOD REQUIREMENT DESCRIPTION

Requirement No.	Description	Priority
Army 1.4d	Lead contamination	High
Air Force 95-1416	Lead migration studies at small-arms ranges	Medium

1.3 Objectives of the Demonstration

The primary objective was to evaluate the performance of SACON as a bullet-trapping material for use in Army outdoor range applications (ref 9). Fourteen types of small-arms ranges are currently in use by the Army (ref 4). Of these, the four ranges described in the following paragraphs were used during the demonstration. These four range types were selected because they have the heaviest usage and the widest applicability throughout the Army and provide a high potential for bullet capture. Also, three of the four types of ranges described consistently receive the M16's 5.56-mm, M855 round (see fig. 1-1). The 5.56-mm round is the most heavily used Army small-arms round (ref 2).

1.3.1 25-Meter (Zero) Range (fig. 1-2). Military 25-Meter Ranges are used to zero rifles and for familiarization firing with a variety of firearms. During this training, each solider shoots an average of 30 rounds at targets mounted in fixed wooden frames, which are always visible to the shooter (ref 9). Bullet traps are considered feasible for use on the 25-Meter Range because large volumes of rounds are fired into a concentrated impact area, which presents a high probability of capturing rounds.

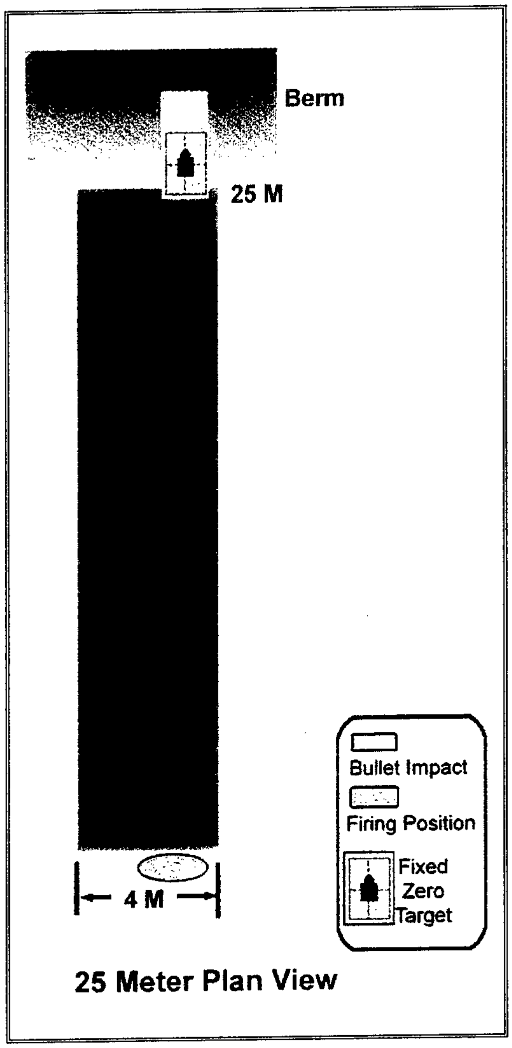


Figure 1-2. 25-Meter Range.

1.3.2 Automated Field Fire (AFF) Range (fig. 1-3). AFF Ranges have pop-up targets located 75, 175, and 300 meters from the firing position. The soldier expends 10 rounds each at the 75- and 300-meter targets, and 20 rounds at the 175-meter target (ref 9). Bullet impacts on this range are concentrated around the target emplacements and, since concealment of target location is not a factor for training realism, bullet traps are feasible for use on this range.

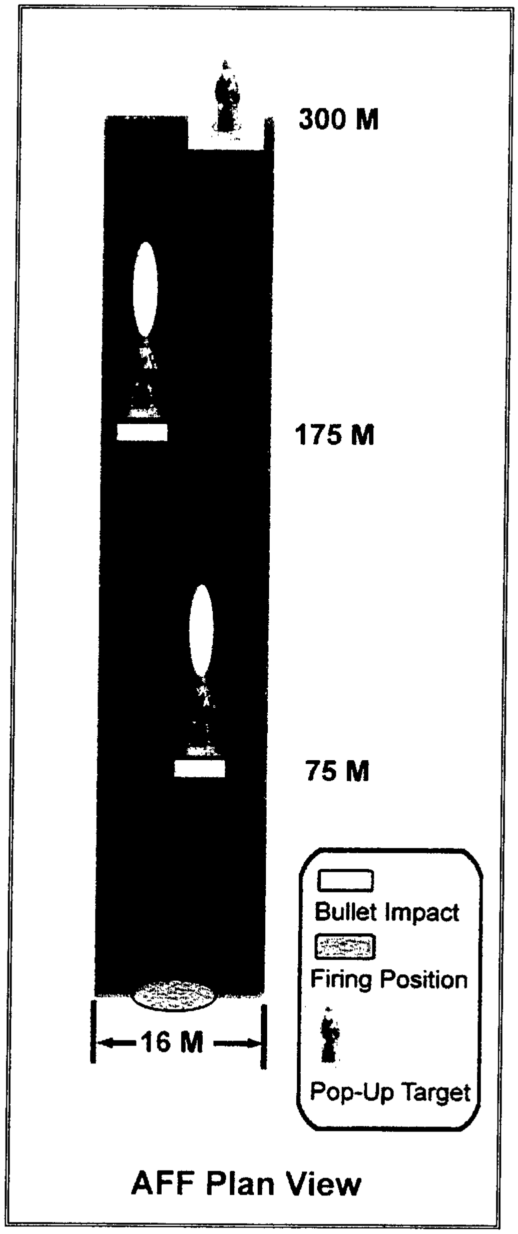


Figure 1-3. AFF Range.

1.3.3 Automated Record Fire (ARF) Range (fig. 1-4). ARF Ranges are used by soldiers to qualify for marksmanship ratings. These ranges are equipped with pop-up targets at six distances (50-meter intervals up to 300 meters). Unlike AFF Ranges, the targets blend into the natural terrain, and the soldier is required to detect one or two of the targets as they are exposed and hit them in a given period of time. Each soldier fires 40 rounds per qualification trial (ref 9). For a bullet trap to be feasible for use on this range, the trap must be capable of being camouflaged to prevent easy target acquisition by the soldier.

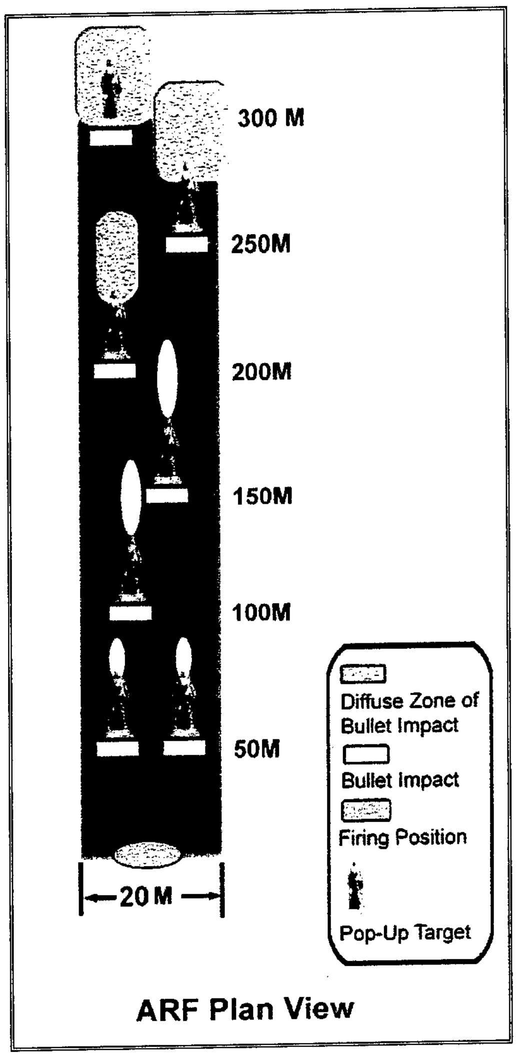


Figure 1-4. ARF Range.

1.3.4 Combat Pistol Qualification Course (CPQC) (fig. 1-5). The CPQC is a pistol range that employs pop-up silhouette targets. Distances to the targets are short compared to the rifle ranges, with seven targets at ranges from 10 to 31 meters (ref 9). Since round impacts are concentrated in a small area and target locations are known, the use of bullet traps is feasible.

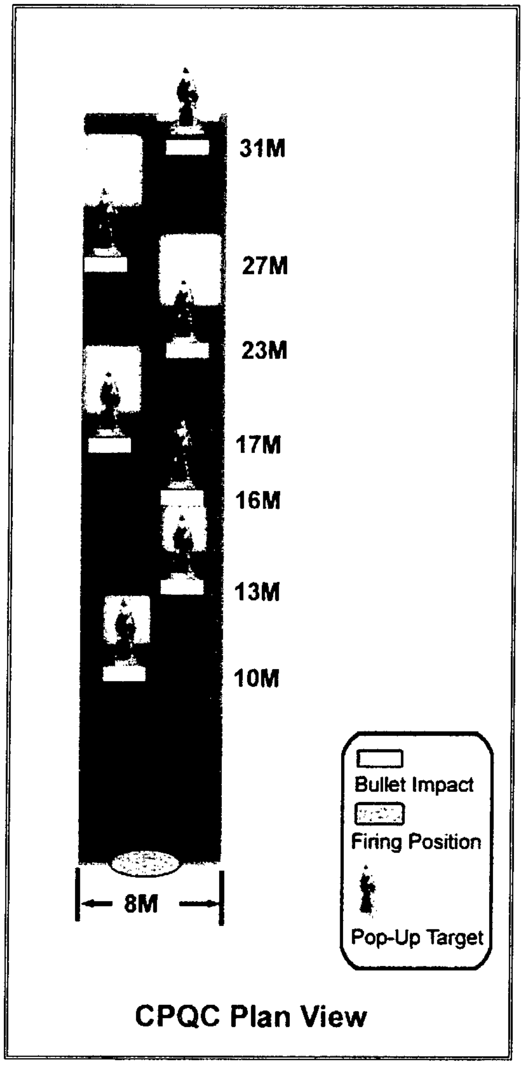


Figure 1-5. CPQC Range.

The demonstration was designed to identify and verify the economic, operational, and environmental performance data that will be used to transfer SACON technology to potential users (ref 9). Six major factors were evaluated: performance, life-cycle costs, safety, logistics, training realism, and recyclability (ref 10).

The demonstration was conducted at the U.S. Military Academy (USMA) West Point, New York; Fort Knox, Kentucky; WES, Mississippi; and the U.S. Army Aberdeen Test Center (ATC), Maryland.

1.4 Regulatory Issues

Prior to the promulgation of the USEPA's Military MR, no federal regulations specifically addressed military munitions or ranges (ref 11). However, federal laws such as the Clean Water Act (CWA); Safe Drinking Water Act; Resource Conservation and Recovery Act (RCRA); Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA); and others can be applied to active small-arms ranges. The law, however, remains unresolved as to the extent to which federal and state regulators can directly affect range activities. While the Army continues to assert that environmental authority does not reach active ranges, prevention is the best course of action in an uncertain regulatory climate.

1.4.1 U.S. Federal Laws and Regulations

1.4.1.1 EPA Military MR and RCRA. The EPA's Military MR defines when military munitions become waste and how RCRA applies to waste munitions (ref 11). As such, munitions (which include small-arms ammunition) are not a RCRA waste when used for their intended purpose (training, research and development, testing, or destruction during range maintenance). It is important to remember that because not all states have adopted the Military MR, the Army has no national standard for applying RCRA to military munitions. States with RCRA authority that have not adopted the Military MR could promulgate more stringent regulations.

1.4.1.2 DOD Range Rule (RR). The proposed DOD RR establishes procedures for evaluating and responding to explosive safety, human health, and environmental concerns on closed, transferring, and transferred military ranges based upon reasonable anticipated future land use (ref 11). Closed ranges include ranges within military control that have been put to a use incompatible with range activities. Transferring ranges include those associated with Base Realignment and Closure (BRAC) activities and other property transfers to nonmilitary entities. Transferred ranges include those in the Formerly Used Defense Sites (FUDS) program. The DOD RR does not apply to active ranges being upgraded, modified, or converted to other training activities such as maneuver areas.

1.4.1.3 CWA. The CWA of 1987 (an amendment to the 1972 Federal Water Pollution Control Act) regulates the discharge of pollutants into U.S. waters, making it illegal to discharge pollutants without a permit. The intent of the CWA is to "restore and maintain the chemical, physical, and biological integrity of the nation's waters." Enforcement actions under the CWA can be applied to Army installations where water quality has been substantially reduced by erosion, and could be applied where lead has migrated to surface water via stormwater runoff or erosion from ranges. Munitions, as a class of items, are defined as a "pollutant" under the CWA, Section 502 (6) (ref 11).

1.4.1.4 Safe Drinking Water Act. The Safe Drinking Water Act of 1974 (amended in 1996), the primary law used to protect the nation's drinking water supply, sets drinking water standards that safeguard the public health against pollutants and contaminants. In April 1997, EPA Region I relied on the Safe Drinking Water Act to stop training (the firing of large- and small-caliber ammunition as well as the use of pyrotechnics and smoke) at the Massachusetts Military Reservation. This was based on allegations that ongoing training activities caused an imminent and substantial threat of contamination to the sole source aquifer under the impact area (ref 11).

1.4.1.5 CERCLA. The CERCLA (enacted in 1980 and extensively amended in 1984) primarily requires remediation at inactive hazardous waste sites. CERCLA, however, is triggered by the release or substantial threat of a release into the environment of a hazardous substance, pollutant, or contaminant that presents an imminent and substantial danger to the public health or welfare. Military munitions, as a class, are not designated as CERCLA hazardous substances (ref 11). However, some constituents of munitions are listed as CERCLA hazardous substances. Examples include ammunition that contains lead, mercury, cadmium, nitroglycerin, ammonium picrate, and phosphorous. DOD is currently evaluating how CERCLA can be applied at military ranges.

1.5 Stakeholder/End-User Issues

From the Range Manager's perspective, adding a bullet trap to their outdoor range creates a burden when compared to current and historic range operations. The burden is created by adding cost, labor, and bullet trap operations and maintenance requirements to range operations. The no-action alternative of shooting into current range impact areas means the Range Manager can continue operations as usual without budgeting or reallocating from an already austere budget for range improvements not designed to improve training realism. If the Range Manager is to install bullet traps on the range, he must do the following: determine an effective type of trap to meet range safety and training realism requirements, prepare the range, install the trap, train and dedicate personnel to operation and maintenance, and deal with the regulatory and administrative concerns created by off-site range debris disposal. In general, it is difficult to convince a Range Manager to take away from current operational funds to save on future clean-up costs.

From an Army management perspective, a balance must be drawn between training needs and today's and tomorrow's budgets. There is no avoiding the nation's need for training ranges to ensure our soldiers are ready for future conflicts. The question becomes "what is the best way to manage resources to complete the mission?" Targeting ranges that are at risk of noncompliance with the draft Military MR should be the first priority in incorporating innovative bullet-trapping technology into range operations. The action is necessary to ensure training operations can continue. The decision to incorporate bullet traps into ranges that are not at risk becomes primarily an economic decision (how much can we invest today to avoid certain costs later) and a balancing of environmental stewardship issues.

1.6 Previous Testing of the Technology

The WES developed SACON as a ricochet-reducing building material for use in live-fire training facilities. Laboratory work and field use of SACON had previously been completed to determine penetration distances of various small arms into SACON of varying densities (table 1-2) (ref 12). WES utilized this information to determine appropriate densities for firing range applications.

TABLE 1-2. PENETRATION DISTANCES

Depth of Projectile Penetration in 1440-kg/m^3 (90-lb/ft^3) Density SACON

Weapon	Typical Depth of Penetration	
	mm	in.
0.38-caliber pistol	25.4	1.00
0.45-caliber pistol	31.7	1.25
9-mm pistol	60.5	2.38
M16A2 rifle (5.56 mm)	63.5	2.50

Ricochet test work conducted at WES determined ricochets did not pose a hazard at angles greater than 10° (ref 13). Ricochet testing at WES included a limited amount of shooting at frozen SACON. WES concluded from this limited testing that ricochet hazards were not changed by the frozen condition of SACON (ref 13).

The WES conducted laboratory testing of field samples to determine typical corrosion products that form on bullet fragments both in soil and in concrete debris (ref 1). The results showed that bullet fragments in soil typically formed lead carbonate corrosion products while fragments from SACON concrete debris formed lead hydroxide. The analysis of these field samples yielded results in agreement with previous laboratory testing (ref 1).

Utilizing these findings, WES sought to improve SACON's ability to reduce the leaching rate of lead from SACON debris (ref 14). Lead leaching is a primary consideration in determining if waste SACON debris that contains bullet fragments must be classed as a RCRA hazardous waste. If the leachate solution from the standard Toxic Characteristic Leaching Procedure (TCLP) (ref 15) contains less than 5 milligrams per liter of leachate, the waste is not considered a hazardous waste based on lead toxicity.

The lead-leaching rate is controlled by the types of corrosion products that form on the metallic lead fragments (ref 14). Typically, a lead carbonate coating will form on lead when the metal is exposed to moisture in a low-pH environment. In higher-pH (alkaline) environments, a less soluble lead hydroxide will form (ref 14).

There are additional, nearly insoluble corrosion compounds that will form on the surface of lead if phosphate is present in the liquid phase around metallic lead (ref 14). The compounds include lead phosphate hydroxide, lead phosphate chloride, and hydrated lead aluminum phosphate hydroxide (ref 14). The natural crystalline forms for these compounds and their solubility product constants are given in Table 1-3 (ref 14).

TABLE 1-3. NATURAL CRYSTALLINE FORMS

Compound	Mineral Analog	Log Solubility Product Constant
Lead carbonate ($PbCO_3$)	Cerussite	-12.8
Lead phosphate hydroxide ($Pb_5(PO_4)_3OH$)	Hydroxypyromorphite	-82.3
Lead phosphate chloride (Pb5 $(PO_4)_3Cl$)	Pyromorphite	-84.4
Basic lead aluminum phosphate ($PbAl_3(PO_4)_2(OH)_5H_2O$)	Plumbogummite	-99.3

1.6.1 Testing of the Effect of Calcium Phosphate. The addition of calcium phosphate was considered as a means to reduce the leaching rate of lead from SACON debris (ref 14). In order to test the usefulness of the proposed SACON/phosphate concrete, four test batches of SACON were prepared using the components and relative weights given in Table 1-4 (ref 14). All ingredients were dry mixed and water was added to form a workable paste. Each batch was cast in a clean plastic tray, covered with plastic film, and allowed to cure for seven days. The concrete samples were then subjected to an acid-leaching test. Each hardened sample was ground so that the material would pass a 9.5-mm (3/8-in.) sleeve. Ten grams of each of the samples were placed in a covered beaker and covered with 200 mL of 0.1-N acetic acid solution. The solution was prepared by diluting reagent grade glacial acetic acid with distilled water. The initial pH of the solution was 2.1. All liquid-solid mixtures were placed on magnetic stirrers in covered beakers and were allowed to stir for 24 hours.

TABLE 1-4. COMPOSITIONS OF SACON TEST MIXTURES, g

Test Mixtures	Mixture Designation			
	Q	QP	C	CP
	CMD Sample No.			
	970291	970292	970293	970294
Portland cement Types I and II	400	400	400	400
Natural river sand (quartz, C33)	400	400	-	-
Ground limestone (calcite, C33)	-	-	400	400
Water (potable)	160	160	160	160
Tribasic calcium phosphate	-	20	-	20
Technical-grade lead powder	10	10	10	10

Q = Quartz sand.
QP = Quartz sand and phosphate.
C = Calcite sand.
CP = Calcite sand and phosphate.

The pH of each mixture was measured after 18 and 24 hours (table 1-5). All samples remained above pH 10.0. After 24 hours, the samples were centrifuged and 10 mL of the clear supernatant liquid (leachate) was collected and diluted to 100 mL using distilled water. The diluted samples were analyzed by inductively coupled atomic absorption spectrometry. The concentrations of lead in each of the leachate samples are given in Table 1-5 (ref 14).

TABLE 1-5. CONCENTRATION OF LEAD AND pH MEASUREMENTS OF ACETIC ACID LEACH LIQUIDS FROM SACON AND SACON-PHOSPHATE MIXTURES

Sample and Sample No.	Pb in Sample, ppm	Pb in Leachate, ppm	pH after 18 Hours, pH units	pH after 24 Hours, pH units
Quartz sand (Q) 70338 Chem Lab 970291 CMD	0.087	0.87	12.0	12.1
Quartz sand and phosphate (QP) 70339 Chem Lab 970292 CMD	.039	.390	10.5	11.8
Calcite sand (C) 70340 Chem Lab 970292 CMD	.031	.310	11.5	12.1
Calcite sand and phosphate (CP) 70341 Chem Lab 970294 CMD	.017	.17	11.5	11.8

1.6.2 Results of Leach Testing. The addition of calcium phosphate to the SACON formulation reduces the amount of lead leached by the 0.1-N acetic acid solution in batches containing either the natural quartz sand or the crushed limestone (calcite) sand. The lowest levels of lead were observed when both calcium phosphate and calcium carbonate were present . This mixture (CP or 970294) produced a lead level that was 20 percent of the lead level from the conventional quartz sand (Q or 970291) mixture. The results indicate that the pH alone is probably not controlling the lead solubility. The formation of an insoluble coating on the lead grains plays a role in reducing lead loss.

The results of the laboratory work were used in filing a Record of Invention by Mr. Dennis L. Bean, Dr. Charles A. Weiss Jr., Dr. Philip G. Malone (Concrete and Materials Division, Structures Laboratory, WES), and Mr. James Sigurdson (Ballastic Technology, Inc., Toronto, Ontario, Canada). The innovative formulation of SACON incorporates low-solubility calcium phosphate compounds that interact with the lead metal fragments to produce an insoluble lead phosphate coating that isolates the lead fragments, greatly reducing the tendency of the lead to dissolve in water (ref 14). The new formulation, referred to as reformulated SACON throughout this report, was manufactured and subjected to limited field testing at ATC.

2. Technology Description

2.1 Description

SACON is a foamed, fiber-reinforced concrete that contains no coarse aggregate. SACON is classed technically as a foamed mortar with a fiber admixture (ref 12). Foamed portland cement-based mortars are produced for industrial applications with densities ranging from 20 lb/ft^3 to densities approaching those of conventional concrete (160 lb/ft^3). Foamed mortars have been widely used as insulation, fire barriers, floor fills, roof decks, and engineered fills for mineshafts. Fiber-reinforced, foamed mortars have been adapted for use in structures designed for live-fire training (fig. 2-1) (ref 12). SACON has a closed cellular structure that breaks down when a bullet impacts the concrete. In a properly designed target system, the incoming bullet buries itself in the concrete and does not ricochet. Previous research has shown that the ability of foamed concrete of a particular composition to stop a projectile varies with the speed of the projectile. For projectiles with speeds of 3000 ft/sec, the strength of the foamed concrete (and secondarily its density) is more important than the type of fiber reinforcement in determining the depth of penetration (ref 12).

SACON has been used in training activities that utilized the M16 rifle firing the M855 round and the M9 pistol firing the M38 Ball ammunition. When used to stop the M16 rifle round (M855 or M193), the density of the SACON bullet barrier is typically 90 lb/ft^3. For ranges that train with the M9 pistol, SACON barriers are furnished with a density of 70 lb/ft^3. The density that is typically presented for SACON is the density of the foamed sand, cement, and water mixture.

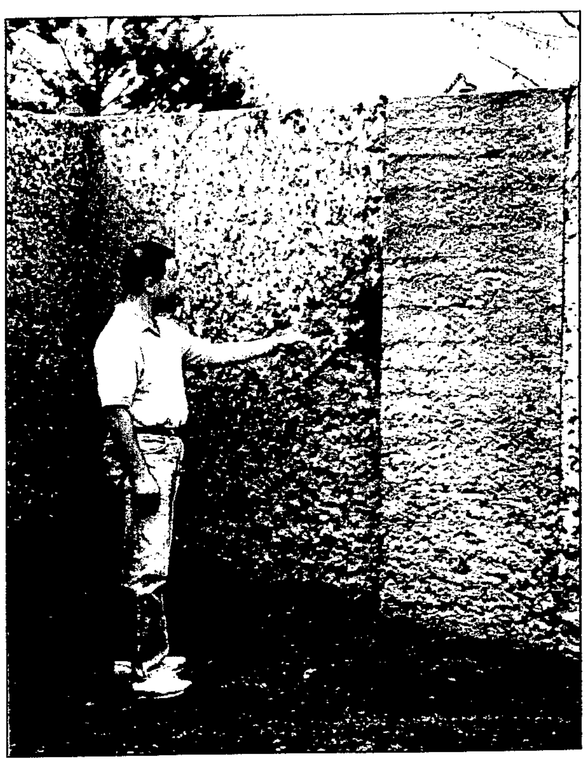


Figure 2-1. Live-Fire Training Facility using SACON.

The innovative use of SACON on small-arms ranges provides DOD with a recyclable material from which to manufacture bullet traps. These traps can be configured to blend into the terrain or to serve as target structures. When applied in certain range configurations, the use of SACON does not detract from training realism. In fact, SACON enhances the ability to hide pop-up targets by reducing the telltale signature created by erosion around the target coffin. Lead bullet debris captured by SACON undergoes a corrosion process, resulting in the formation of a relatively insoluble coating on the bullet fragments. Less-soluble lead fragments reduce the leachability of the lead. Reduced solubility and erosion subsequently reduce the potential for lead migration from range areas.

2.1.1 SACON Components

The materials required to manufacture SACON are presented in Tables 2-1 and 2-2 (ref 12).

TABLE 2-1. PROPORTIONING OF MATERIALS FOR SACON WITH 1440 KG/M^3 (90 LB/FT^3) DENSITY

Material	Steel-Fiber Reinforced		Polypropylene-Fiber Reinforced	
	kg/m^3	lb/yd^3	kg/m^3	lb/yd^3
Portland cement (ASTM Types I and II)	577	972	577	972
Water	277	466	277	466
Aggregate	577	972	577	972
Admixture	0.16	0.27	0.16	0.27
Fiber	114.5	193	8.78	14.8
Foam	329 L/m^3	8.9 ft^3/yd^3	329 L/m^3	8.9 ft^3/yd^3

ASTM = American Society for Testing Materials.

TABLE 2-2. PROPORTIONING OF MATERIALS FOR SACON WITH 1120 KG/M^3 (70 LB/FT^3) DENSITY

Material	Steel-Fiber Reinforced		Polypropylene-Fiber Reinforced	
	kg/m^3	lb/yd^3	kg/m^3	lb/yd^3
Portland cement (ASTM Types I and II)	322	710	322	710
Water	145	320	145	320
Aggregate	322	710	322	710
Admixture	0.11	0.25	0.11	0.25
Fiber	87.7	193	6.7	14.8
Foam	514 L/m^3	13.9 ft^3/yd^3	514 L/m^3	13.9 ft^3/yd^3

2.1.1.1 Aggregate. SACON is proportioned with no coarse aggregate. Specifications for the fine aggregate (sand) used in a SACON mixture were selected to exclude any particles larger than 9.5 mm (0.36 in.). Sand that meets the requirements set out in American Society for Testing Materials (ASTM) C 33-93, Standard Specifications for Concrete Aggregates, Fine Aggregates (ref 16), is generally acceptable. However, it may be prudent to specify fine aggregate that meets ASTM C 144-89, Standard Specification for Aggregate for Masonry Mortar (ref 17). The largest particles permitted under this specification must pass a 4.75-mm (0.18-in.) sieve. Table 2-3 presents the size grading for each specification. The selection of a specification depends on the ability of the vendor to consistently meet the size requirements in the specification. Sand that meets the C 144-89 standard (masonry sand) is generally more expensive than sand that meets the C 33-93 standard (concrete sand), but there is the assurance that there is less likelihood of aggregate particles of sizes greater than 9.5 mm being in the final concrete mixture. The introduction of coarse aggregate into SACON can produce ricochets if a bullet impacts on a piece of coarse aggregate.

TABLE 2-3. AGGREGATE SPECIFICATION

ASTM C 33			ASTM C 144 % Passing Sand	
Sieve Specification		% Passing	Natural	Manufactured
3/8-in.	(9.5 mm)	100	-	-
No. 4	(4.75 mm)	95 to 100	100	100
No. 8	(2.36 mm)	80 to 100	95 to 100	95 to 100
No. 16	(1.18 mm)	50 to 85	70 to 100	70 to 100
No. 30	(600 μm)	25 to 60	40 to 75	40 to 75
No. 50	(300 μm)	10 to 30	10 to 35	20 to 40
No. 100	(150 μm)	2 to 10	2 to 15	10 to 25
No. 200	(75 μm)	-	-	0 to 10

Both natural and manufactured sands are suitable constituents for SACON. Manufactured sands made by crushing larger aggregate contain more angular particles than do natural sands from sand deposits or stream dredging. Manufactured sands typically require more water to wet the surfaces and require more effort to finish to a smooth surface. Neither of these factors is a serious consideration in casting SACON. Either type of sand is acceptable.

2.1.1.2 Cement. SACON is proportioned with cement that conforms to ASTM C 150-89, Standard Specification for Portland Cement, as a Type I or II portland cement (ref 18). To obtain uniform results, it is best if all of the cement used in a particular mixing operation is of one type and is obtained from one source. Pozzolanic additives are not normally used in SACON because these materials extend the curing time that is required to obtain a designated strength.

In mixing SACON, the cement is introduced slowly into the water-sand slurry in the mixer to minimize the formation of "cement lumps". Cement lumps form easily because there is no coarse aggregate to facilitate mixing. In the mixing process, it is important that the cement be introduced into the mixture as a free-flowing powder. The most uniform SACON is produced using fresh cement that is stored in bulk (dispensed from silos). Bagged cement, especially bagged cement that has aged and has a "bag set", can produce an unacceptable number of hard lumps (referred to as cement balls). Cement balls that are larger than 9.5 mm in diameter can potentially produce ricochets if struck by an incoming round much the same as would be produced by coarse aggregate particles. Also, cement that is not distributed in the mixture will not hydrate to produce the gel that bonds the grains of aggregate together. The formation of lumps has the effect of removing a portion of the cement from the mixture and results in a weaker concrete product that will have a shortened service life. The goal in selecting the cement and conducting the mixing operation carefully is to make a smooth, uniform, "batter-like" mixture.

2.1.1.3 Admixtures. SACON (like all foamed mortars) consists of two particulate materials, cement and sand, in a watery mixture. Quartz sand has a density of approximately 2.78 g/cm^3 and portland cement has a density of 3.15 g/cm^3. The density differences are such that the two phases will separate in a watery suspension. In order to assure that the materials remain suspended, it is necessary to add a thickener to increase the viscosity of the mixture. The most compatible thickeners are methyl cellulose ethers (hydroypropyl methyl cellulose). The usual grade used in SACON is 19.0- to 24.0-percent methoxyl methyl cellulose and 7.0- to 12.0-percent hydroypropyl methyl cellulose. Thickeners are furnished as a dry powder and cannot be added directly to the water mix because they tend to clump immediately on wetting. The thickener is routinely added to a portion of the dry cement and dispersed through the cement. The dry, blended powders are then added to the water in the mixer.

2.1.1.4 Foaming Agents. A variety of foaming agents are available for making preformed foam for cellular concrete. Products are typically described as being animal protein-based materials made by digesting scleroprotein such as feathers, hair, or fish scales in a strong alkali solution or synthetic agents which are typically proprietary surfactants in a water-alcohol solution. Specifications listed in ASTM C 896-91 (ref 19) for foaming agents are based on the ability of the agent to produce a cellular concrete with a density of 641 kg/m^3 (40 lb/ft^3) and an unconfined compressive strength of 1.4 MPa (200 psi) under the specific conditions described in ASTM C 796-93 (ref 20). Any foaming agent meeting the ASTM C 896-91 specification should be acceptable.

Foaming agents are typically furnished as a liquid concentrate that must be diluted approximately 40:1 with potable water prior to use in a foaming pump. Pumps that generate foam can be purchased in a variety of designs. All designs are based on mixing air with the surfactant solution and forcing the mixture through screens or packed beads to generate the foam. Often particular pump designs work best with specific foaming agents. The pump and foaming agent can be obtained as a system or separately.

2.1.1.5 Fibers. Fibers are generally used to increase the fracture toughness of concrete, although steel fibers can produce an increase in the unconfined compressive strength and the modulus of rupture when used in dosages of over 3 percent by volume. Synthetic organic fibers are generally used only to increase the fracture toughness of the concrete and help to control shrinkage cracking during curing (ref 12).

Almost any commercially available fiber that is marketed for concrete reinforcement and meets ASTM C1116 (ref 21) is suitable for use in SACON. Nylon, polypropylene, and fibrillated (branched) polypropylene fibers have all been successfully used in SACON. The fibers should have a minimum length of 13 mm (0.75 in.). Fibers up to 37 mm (1.5 in.) in length have been successfully used, although long fibers are more difficult to evenly distribute throughout the fresh concrete during mixing due to the tendency for the fibers to "ball up". Fibers that do not become dispersed in the mixture produce weak spots and do not contribute to the toughness of the concrete. If long fibers are used, the fresh concrete must be moved with a bucket or chute. Long fibers will typically clog pumping equipment. Because there is no coarse aggregate in SACON mixtures, it is necessary to add the fiber in a loose form in small quantities to the mixer. Prepackaged fiber typically will not be dispersed in the mixture and often the bags of fiber will not be opened by the mixing action because of the lack of coarse aggregate. SACON requires approximately 9.0 kg of fiber/m^3 (15 lb/yd^3). This large proportion of fiber (1-percent fibers by volume) is approximately the maximum amount of fiber that can be dispersed evenly using a rotating drum mixer.

While both steel and synthetic fibers were used during the demonstration, steel fibers are not recommended for use on the range. Steel fibers pose a handling problem when SACON debris is gathered from the range. Range personnel received superficial punctures and cuts through leather gloves while handling SACON debris made with steel fibers.

2.1.1.6 Pigments. Almost any commercially available pigment recommended for use with air-entrained concrete can be used in SACON. Most commercial pigments used in concrete are iron oxides. Pigments made with heavy metals (especially nickel or chromium compounds) should be avoided due to the possibility of leaching toxic metals into the local soil or groundwater. Pigments that contain carbon can be deleterious to the bubble structure of the concrete and should also be avoided.

2.1.2 Reformulated SACON

In 1998 (during the demonstration), WES and Ballistic Technology, Inc., developed an innovative formulation for SACON (ref 14) designed to further reduce the leaching rate of lead captured by SACON. The reformulated SACON incorporated low-solubility calcium phosphate compounds interacting with the lead metal fragments to produce a relatively insoluble lead phosphate coating. The coating serves to isolate the lead fragments and greatly reduces the tendency of the lead to dissolve in contacting water (ref 14). The reformulated SACON made with calcium phosphate compounds was reported to be as easy to manufacture as the conventional SACON with the volume and cost of the phosphate compounds not appreciably increasing the cost of the finished bullet-trap material (ref 14).

The reformulated SACON mixture used in this demonstration was prepared by adding tribasic calcium phosphate in an amount equal to 0.1 percent of the mass of the cement to the components listed in Table 2-1. The reformulated SACON used limestone sand in place of the quartz sand used in the original formulation.

2.2 Strengths, Advantages, and Weaknesses

2.2.1 Existing Technologies.

2.2.1.1 Impact Berms (Conventional Technology). DOD operates approximately 1800 small-arms ranges. Many of these ranges currently use soil berms to terminate the flight of the small-arms rounds (fig. 2-2). The maintenance requirements to operate a range using berms are minimal. The maintenance consists primarily of infrequently adding soil to the berm for surface repair. The total annual range maintenance costs for the five 25-Meter Range berms at Fort Jackson, South Carolina, are approximately $15,000 (ref 22). The life expectancy of the berm is defined as the length of time before a soil/bullet removal and remediation action is required. In the past, berm cleanups were not necessitated by environmental requirements. However, now to be in compliance with the Military MR, contaminant transport must be localized to the range. Thus, future clean-up frequencies will need to be based upon lead transport risks at individual ranges. There are five principal parameters that contribute to assessing the overall risk associated with lead migration from a small-arms range. These parameters are ammunition mass fired, corrosion, aerial transport (dust), surface water transport, and groundwater transport. These parameters can be qualitatively assessed using AEC's Range Evaluation Software Tool (REST) (ref 23).

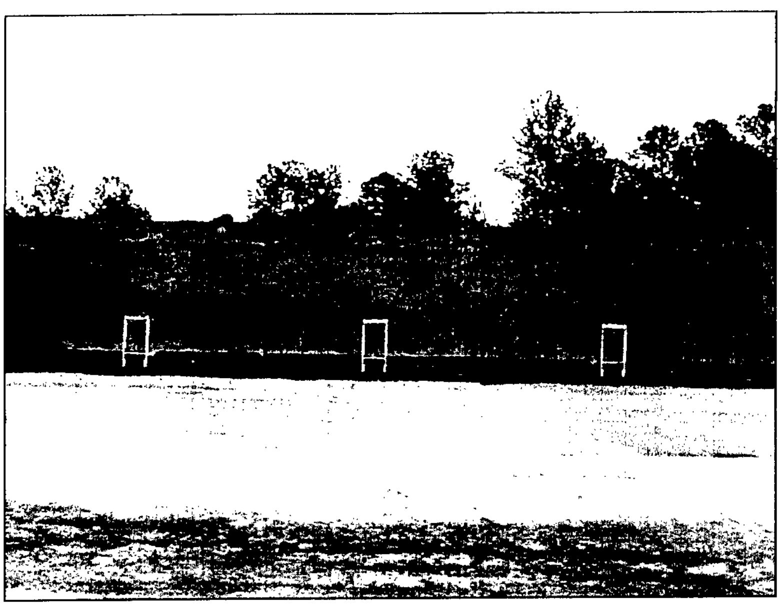


Figure 2-2. Small-arms range berm.

2.2.1.2 Bullet Traps. Many bullet-trapping options are available for range use. The *Bullet Trap Feasibility Assessment* (ref 4) differentiated the existing small-arms range bullet traps by developing three categories referring to the physical mechanism utilized to stop bullets. The three categories were deceleration, impact, and friction (ref 4). Typically, deceleration traps use angled steel plates to deflect bullets into a helical chamber where bullets spin until they lose velocity and drop into a collection chamber (fig. 2-3).

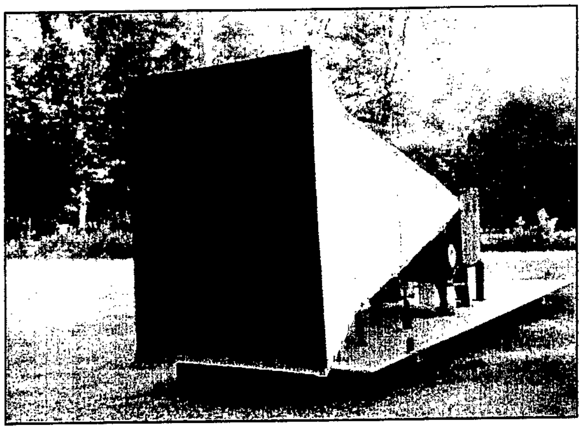


Figure 2-3. Deceleration trap.

Impact traps stop a bullet at its initial contact with the trap material, which is usually a steel-backed wooden box (not shown). Friction traps use a medium (such as wood, rubber, soil, plastic, or SACON) to slow and eventually stop the bullet (fig. 2-4 and 2-5).

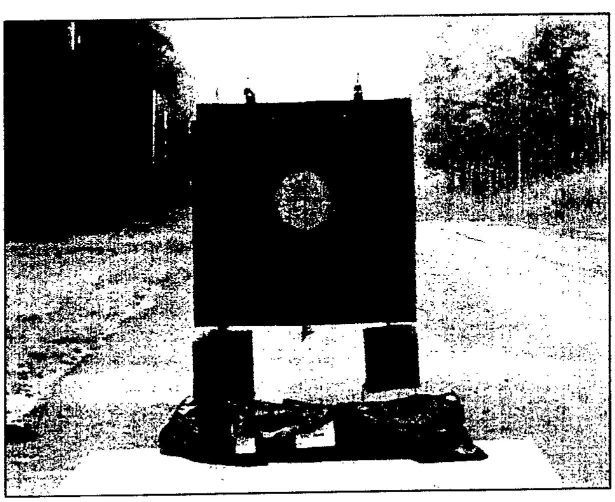


Figure 2-4. Rubber block friction trap.

Figure 2-5. Granular rubber friction trap.

2.2.1.3 Advantages. SACON has significant advantages over other friction trap materials such as rubber blocks, granular rubber, or wood in that SACON does not burn. A rubber trap used on an outdoor range is likely to be damaged significantly during its life on the range. Range impact areas are generally maintained in a grassed-over condition to minimize erosion and range run-off (ref 28). During hot, dry weather, the grass dries out and fires become a potential problem. Range fires can be caused by a number of mechanisms including tracer rounds, muzzle flash, and lightning. Rubber bullet traps on the range are susceptible to consumption by the range fire. Burning rubber complicates fighting range fires by creating a hot, smoky fire that produces complex hydrocarbons generally containing carcinogens (ref 28). Rubber fires produce a thick, black smoke visible for miles (fig. 2-6) and can generate nuisance complaints from neighbors and inquiries from the regulatory community.

Figure 2-6. Rubber fire.

SACON has significant advantages over deceleration traps in that no back-splatter and less lead dust are created.

SACON has a number of characteristics that make it valuable as a bullet-trapping medium when compared to traditional berm technology. The low permeability of SACON reduces the amount of lead (from bullet debris) that is exposed to weathering on the range. The high alkalinity of SACON can reduce the rate of lead corrosion and decrease the solubility of the lead corrosion products, thus lowering the amount of lead available for migration. SACON can also be used to stabilize areas typically rutted by bullet impacts, such as around target coffins or within berm cavities.

SACON does not have to be treated with any preservative, will not rot, and is not subject to attack by insects. SACON will not photodegrade as rubber does and contains no potentially toxic organic compounds that can appear in water leaching from the material. SACON can be locally manufactured and can be camouflaged with range terrain.

SACON can be crushed to reclaim bullet debris and to produce an aggregate for use in the manufacture of additional SACON although the recycling will be governed by economics. SACON can be manufactured and colored into shapes typical to ranges. The installation of SACON does not require extensive site preparations, with SACON walls requiring only a level, solid foundation.

While debris removed from soil berm cavities has been found to have leachable levels of lead greater than 5 ppm, SACON debris when analyzed for leachable lead content was consistently nonhazardous (less than 5-ppm TCLP lead) (ref 64). Debris samples taken from friction traps constructed of media other than SACON have consistently failed the TCLP criterion for a characteristic hazardous waste based on lead concentration. The hazardous classification results in more expensive handling and disposal requirements for the range debris generated from the use of traps using rubber or soil as the friction media. The reduced mobility of lead created by SACON makes landfilling of spent SACON a viable option.

2.2.1.4 Weaknesses. The manufacturing of SACON requires careful quality control to ensure that the correct densities are produced and that only the proper-size aggregate is used. Improper manufacturing has the potential to create safety problems. Density is a primary factor in the materials performance as a trapping medium. SACON with densities or aggregates greater than specified may create a ricochet hazard.

At the present time, the recycling of bullet-trap media does not appear to be economically advantageous. Discussions with the recycling industry indicated that the lead debris recovered must contain greater than 85-percent lead before the value of the metal exceeds the recovery cost (ref 32). The SACON debris removed from a wall requiring maintenance had total lead levels ranging from 8 to 14 percent, well below the industry-supplied feasibility limit. If bullet-trapping media were to be recycled, the used material to be recycled would have to be stored until a sufficient volume of material had accumulated to warrant a recycling operation. Storing the potentially hazardous material from SACON or from other bullet-trapping devices creates storm water management, material storage, and RCRA issues to be addressed by the Range Manager. Any recycling effort would require the services of a qualified waste disposal contractor. Operations involving lead-contaminated concrete would require an engineered facility as the recycling operation itself produces a lead-contaminated dust from crushing the SACON, creating the potential for contamination of the recycling site.

SACON barrier design improvements are needed to reduce handling requirements and improve durability. A constraint placed upon bullet barrier designs was man-portability of each barrier block component. However, the SACON blocks used in this demonstration for the 25-Meter Range application required lifts exceeding human factors lifting guidelines. Some of the SACON blocks shaped to simulate logs or stumps on the ARF, AFF, and CPQC Ranges also exceeded lifting guidelines. The simulated logs and stumps also required more frequent maintenance than wood.

2.3 Factors Influencing Cost and Performance

Several factors influence the cost and performance of SACON bullet traps. Cost can be influenced by the scale of manufacture, configuration (shape) of the SACON products, installation on the range, range throughput and bullet-trap durability, maintenance frequency, maintenance techniques, and waste recycling or disposal availability. Performance can be influenced by manufacturing quality control, configuration of the SACON products, and installation and location of the SACON on the range.

2.3.1 Cost. The scale of manufacture will have some influence on the cost of the SACON. Contracting to fabricate small quantities of SACON (10 to 20 cubic yd) may be difficult or more expensive. Although the mixing process and components are standard and readily available, the quality control necessary to ensure that the SACON meets the appropriate density specification may result in vendors trying to charge a premium price for the material. This seems to be more prevalent when small quantities are being mixed because the profit potential is not as great and the operators are not accustomed to maintaining the level of quality needed. When larger quantities are being produced, quality control becomes a more routine part of the operation and the risk to the contractor of producing off-specification SACON is reduced.

The configuration or shape of the SACON being fabricated influences the cost. Complicated shapes will increase the mold fabrication costs as well as increasing the labor requirements for demolding the SACON. Also, complicated molds increase the time required to manufacture the large volume of SACON needed to outfit a range. Simple block molds and slabs that can be easily cut to the appropriate size allow for the inexpensive and quick production of SACON.

The method of installation of SACON on the range will influence the cost. SACON can be employed for several purposes on a small-arms range. Each application will require different site preparation and material-handling requirements. For example, the use of SACON as a backstop on a 25-Meter Range requires leveling of the site and stacking of the blocks to form the backstops. This demonstration employed man-portable blocks; however, larger blocks moved by forklift can be used to accelerate backstop assembly and reduce manpower requirements. The use of SACON on an ARF Range to mitigate impact area erosion in front of and behind the targets requires excavation to a depth of 6 to 8 inches deep to bury blocks. This excavation and placement of the SACON can be performed with heavy equipment or with manual labor, depending on the accessibility of the site.

Range throughput and SACON durability influence the cost of maintaining the SACON bullet traps on a range. High range throughput (or high number of personnel using the range) results in a large number of rounds being fired on each firing position. For example, a firing position on a 25-Meter Range at a basic training installation may receive as much as 30,000 rounds per year. Depending on the durability and thickness of the SACON backstop, this volume of rounds may require three to four maintenance events per year on each backstop. The maintenance will involve removal of the SACON debris, classification of the debris as a hazardous or a nonhazardous waste, disposal/recycling of the SACON debris, and refurbishment of the SACON backstops with new SACON blocks. Other range applications of SACON may require more or less frequent maintenance than that for the 25-Meter Range, depending on the SACON's durability in the specific application; however, the actions involved in maintaining the SACON will be the same as those described for the 25-Meter Range.

Waste recycling or disposal costs will vary with the lead content and hazard classification of the debris removed from the range. According to a recycling industry representative, a lead content of approximately 85 percent is needed before the value of the metal exceeds the recovery operation costs. This cost may be mitigated somewhat by the value of the recovered aggregate for reuse in producing new SACON; however, the value of the aggregate is not very high. The required lead content is also dependent upon the market value of lead. As lead prices increase, the content required to make lead recovery economically viable will decrease. Disposal costs vary with the hazard classification of the waste. All waste (SACON debris) removed from the ranges at Fort Knox, Kentucky, and USMA West Point, New York, has been classified as a solid waste. No hazardous waste characteristics were exhibited; therefore, the higher handling and disposal costs associated with handling hazardous wastes were avoided. One other factor that may influence either recycling or disposal costs is the proximity of the installation to recycling facilities or landfills. Transportation costs will increase with a greater distance to these facilities.

2.3.2 Performance. Manufacturing quality control can affect SACON in basically two ways. First, poor quality control could result in the production of SACON that has a density too high for its intended purpose or with greater than 9.5-mm coarse aggregate or cement balls. These conditions could result in ricochets that travel beyond a range's established safety danger zone (SDZ). Second, if poor quality control results in the production of SACON that has a density too low for its intended purpose, then rapid wear will result in increased maintenance frequency and cost.

The configuration or shape of the SACON products has a significant effect on the durability of the material. Shapes with curved surfaces were observed to deteriorate faster during use than shapes with flat surfaces. This was found to be true regardless of the size of the shapes. This increased rate of wear results in increased maintenance frequency and cost.

The installation and location of SACON on the range also affects its durability. Proper location of the SACON on the range is essential to its performance. It must be located such that the majority of the rounds fired impact at or near its center mass. If a significant volume of rounds impact near the edges of the SACON, then the durability of the overall SACON backstop will be decreased due to the increased rate of wear that occurs near the edges of the SACON blocks. (Note: The increased wear rate observed on SACON shapes with curved surfaces is attributed to this increased edge wear.) Not only does the proper location of the SACON on the range affect its performance, but its size and the method of installation affect its durability. If a backstop is too small, then the edge effects previously discussed will accelerate wear. Backstop applications require a sufficient mass to be able to absorb rounds for a prolonged period of time. A backstop depth of 4 to 5 feet is needed to provide acceptable durability. Also, loosely stacked backstops will result in accelerated wear to the blocks making up the stack. A tightly stacked backstop will reduce the edge wear effects on the individual blocks in the stack and provide a large mass to absorb the impact of the rounds for prolonged periods of time. The SACON blocks buried in impact areas did not appear to be significantly affected by block size or depth. Factors influencing the cost and performance of SACON are summarized in Tables 2-4 and 2-5.

TABLE 2-4. FACTORS INFLUENCING COST

Cost Categories	Factors Influencing Categories	Effects Produced By Factors
Fabrication	Scale of Manufacture (Quality Control)	Premium prices may be charged for fabrication of small volumes of SACON.
	SACON Configuration	Complicated molds increase cost and fabrication time.
Installation	Range Application	Determines the type of site preparation and the accessibility of material handling equipment.
	Site Preparation	Costs vary with site preparation requirements.
	Material Handling	Ability to use material-handling equipment reduces manpower requirements and installation timeframe.
Maintenance	Range Throughput	A high number of personnel using the range will result in more frequent maintenance.
	Durability	Durability varies with range application and throughput affecting maintenance frequency and range availability.
	Debris Removal	Requires waste handling training and appropriate personnel protective equipment (PPE).
	Waste Classification	Sampling and analysis are required to determine the waste handling and disposal requirements. Waste classification may be dependent upon range throughput. Record keeping required.

TABLE 2-4 (CONT'D)

Cost Categories	Factors Influencing Categories	Effects Produced By Factors
	Waste Handling	Range residue produced requiring proper handling, storage, disposal, and record keeping. Volume of waste is dependent upon range throughput.
	Refurbishment	Durability, throughput, and range application dependent. Generation of replacement SACON necessary.
Recycling/ Disposal	Disposal/Recycling	Waste material characteristics and volume generated are throughput and application dependent. Aggregate value and cost to generate should be compared to disposal fees.

TABLE 2-5. FACTORS INFLUENCING PERFORMANCE

Influencing Factors	Effects Produced By Factors
Quality Control	Densities off specification will affect durability and possibly SDZs for the ranges.
SACON Shape	The mass and shape of the SACON barriers affect durability and containment performance.
Range Application	The dispersion of the shots affects durability and containment performance.
Site Preparation	Affects the stability of the barriers and subsequently durability and containment performance.
Installation Method	The tightness of the stack affects the durability of the barrier.
Range Throughput	The number of rounds fired affects maintenance frequency.

3. Site/Facility Description

3.1 Background

The field test sites were selected to provide both operational data and detailed performance data. User input was gained through the application and use of SACON on training ranges located at USMA West Point, New York, and Fort Knox, Kentucky. These two sites were selected jointly by AEC and the U.S. Army Training Support Center (ATSC) (location). The range site selections were made based upon willingness to provide data collection support for the demonstration, existence of applicable small-arms range types, target receive rates, and training schedules.

A total of four demonstration sites were selected. Two training range sites pledged the support of installation personnel to conduct data collection activities such as recording range utilization parameters and taking depth-of-penetration measurements. USMA West Point, New York, agreed to the placement of SACON on both 25-Meter and ARF Ranges and to the collection of debris samples. Fort Knox, Kentucky, allowed SACON to be placed on 25-Meter, AFF, ARF, and CPQC Ranges. All of the ranges are actively used and were categorized as high-target-receive-rate ranges. A range with a high target-receive rate was estimated to have in excess of 20,000 to 30,000 rounds fired from each individual firing point per year (ref 33). The training schedule at Fort Knox was expected to be heavier than at the USMA West Point site. Historically, Fort Knox's Range Division had reported the expenditure of 4,647,256 M16 rounds in FY96 (ref 34). USMA West Point was expected to have a lower ammunition expenditure rate and a training schedule that was impacted by winter weather. A monthly usage rate of 7000 rounds per 25-Meter Range firing lane was anticipated and necessary for the success of the durability portion of the demonstration. Unfortunately, the range usage rates were less than expected, with a demonstrated rate of 5000 to 8000 rounds per firing lane.

Initially, the manufacture and recycling of SACON were to be performed at Fort Knox. However, the manufacture and recycling of SACON were conducted at WES because of the small volume of material needed for the demonstration.

Accelerated durability, simulated leaching, and ricochet tests were conducted at ATC. The accelerated durability testing was necessitated since the field data collection methodology was inadequate in design to accurately produce a depth-of-penetration versus rounds fired analysis. Also, during the field demonstration period, the volume of rounds fired was much lower than expected. ATC was selected because of their abilities to conduct advanced technology and early operational testing projects.

4. Demonstration Approach

4.1 Performance Objectives

The demonstration was designed to identify and verify the economic, operational, and environmental performance data that will be used to transfer this technology to potential users. Six major factors are being evaluated: performance, life-cycle costs, safety, logistics, training realism, and recyclability (ref 10). Table 4-1 outlines the objectives to be addressed during this demonstration. Figure 4-2 identifies the demonstration locations from which the various data elements were generated. The evaluation criteria are presented in Table 4-2.

Field demonstration activities were conducted at USMA West Point from April through November 1997 and at Fort Knox from March 1997 through January 1998 (fig. 4-1). The recycling operation was conducted in October 1997. Accelerated durability and ricochet tests were conducted at ATC in March 1998.

Figure 4-1. Training - 25-Meter Range.

TABLE 4-1. OBJECTIVES

Objective 1.0 Assess the performance of SACON bullet traps on small-arms firing ranges.

Objective 1.1	Assess the number of rounds not retained by the SACON bullet traps.
Objective 1.2	Determine if debris is RCRA hazardous waste based on toxicity characteristics.
Objective 1.3	Assess the effect on impact erosion of SACON bullet traps.
Objective 1.4	Assess the effect of SACON on target protection.

Objective 2.0 Determine the life-cycle costs associated with using SACON bullet traps.

Objective 2.1	Determine the nonrecurring costs associated with SACON bullet traps.
Objective 2.2	Determine the recurring costs associated with SACON bullet traps.

Objective 3.0 Assess selected safety issues related to using SACON bullet traps.

Objective 3.1	Determine if SACON bullet traps produce ricochets.
Objective 3.2	Assess personnel safety during SACON barrier installation and maintenance.

Objective 4.0 Assess selected logistical issues associated with SACON.

Objective 4.1	Assess the maintainability of the SACON bullet traps.
Objective 4.2	Assess the durability of the SACON bullet traps.

Objective 5.0 Assess the impact of SACON bullet traps on training realism.

Objective 5.1	Assess the distraction to the shooter caused by the SACON bullet traps.
Objective 5.2	Assess the down-range visibility impact caused by SACON.
Objective 5.3	Assess the ability of the SACON to conceal target location.

Objective 6.0 Assess the performance, costs, and safety aspects of recycling SACON.

Objective 6.1	Determine the ability to remove steel penetrators and/or steel fibers.
Objective 6.2	Determine the ability to reduce toxicity characteristics.
Objective 6.3	Determine the ability to contain and control lead.
Objective 6.4	Determine if the waste material generated is a hazardous waste.
Objective 6.5	Determine the ability to generate a usable fine aggregate.
Objective 6.6	Determine the ability to produce SACON conforming to specifications.
Objective 6.7	Determine the nonrecurring (capital) cost associated with recycling.
Objective 6.8	Determine the recurring cost associated with SACON recycling.
Objective 6.9	Assess personnel safety during the SACON recycling demonstration.
Objective 6.10	Determine the adequacy of personnel protective equipment (PPE).

RANGES	1-1 Fragment Containment	1-2 Toxicity Characteristics	1-3 Impact Erosion	1-4 Target Protection	2-1 Capital Costs	2-2 Recurring Costs	3-1 Riccochet Characteristics	3-2 Personnel Safety	4-1 Maintainability	4-2 Durability	5-1 Firer Distraction	5-2 Downrange Visibility	5-3 Target Concealment	6-1 Steel Removal	6-2 Toxicity Characteristics	6-3 Lead Containment	6-4 Waste Characterization	6-5 Production of Aggregate	6-6 Physical Characteristics	6-7 Non recurring costs	6-8 Recurring costs	6-9 Personnel Safety	6-10 Protective Equipment
Fort Knox																							
25-Meter Range		●					●	●	●	●	●												
ARF Range		●	●	●					●			●	●										
AFF Range		●	●	●					●			●											
CPQC		●	●	●					●			●											
USMA																							
25-Meter Range	●	●			●	●	●	●	●	●	●												
ARF Range			●	●					●			●	●										
ATC	●	●				●	●	●	●	●													
WES														●	●	●	●	●	●	●	●	●	●

Figure 4-2. Objectives versus primary data collection locations.

TABLE 4-2. TEST CRITERIA

Objective	Description	Criteria
	1.0 Performance	
1.1	Bullet containment efficiency	98%
1.2	Characterization of waste products	<5 ppm leachable lead
1.3	Reduction of impact erosion	None
1.4	Adequacy of target protection	None
	2.0 Costs	
2.1	Nonrecurring costs	None
2.2	Recurring costs	None
	3.0 Safety	
3.1	Ricochet hazard	AR 385-64
3.2	During installation and maintenance	OSHA 29 CFR 1910
	4.0 Logistics	
4.1	Maintainability	None
4.2	Durability	None
	5.0 Training Realism	
5.1	Distraction	None
5.2	Visibility impact	None
5.3	Ability to conceal	None

TABLE 4-2 (CONT'D)

Objective	Description	Criteria
6.0 Recycling		
6.1	Steel removal efficiency	>95% removal
6.2	Reduction of toxicity characteristics	<5 ppm leachable lead
6.3	Containment and control of lead	<200 ppb per square foot accumulation
6.4	Characterization of waste products	<5 ppm leachable
6.5	Production of usable fine aggregate	Meets specification
6.6	Physical characteristics	<5% deviation
6.7	Nonrecurring costs	None
6.8	Recurring costs	None
6.9	Personnel safety during recycling	OSHA 29 CFR 1910
6.10	Personal protective equipment	OSHA 29 CFR 1910

ppm = Parts per million.
ppb = Parts per billion.

4.2 Physical Setup and Operation

4.2.1 Manufacturing SACON

4.2.1.1 Material Quality Control Requirements for SACON (ref 12). SACON is manufactured by combining cement, water, sand, fiber, and foam in the absence of coarse aggregate. In specifying handling procedures for aggregate in SACON, it is necessary to require that the materials be stored in areas where coarse aggregate cannot be accidentally mixed into the aggregate to be used in making SACON. Further, it is important to require that any mixer be completely emptied and inspected to assure that coarse aggregate is not inadvertently mixed into the concrete (fig. 4-3). Because there is no coarse aggregate in SACON mixtures, it is necessary to add fibers in a loose form in small quantities to the mixer to ensure uniform mixing in the SACON. Producing SACON using fresh cement that is stored in bulk enhances quality control. Bagged cement often has a bag set which can produce an unacceptable number of hard lumps or cement balls. With no coarse aggregate in the mixture, these balls are not easily broken up. As with aggregate particles, cement balls that are larger than 9.5 mm in diameter can potentially produce ricochets if struck by an incoming round.

4.2.1.2 Mixing, Placing, and Curing SACON (ref 12). SACON is prepared like any other cellular concrete. The rotary drum action of a transit mix truck (fig. 4-4) works well for grout (sand/cement/water) mixtures that have densities greater than 800 kg/m^3 (50 lb/ft^3).

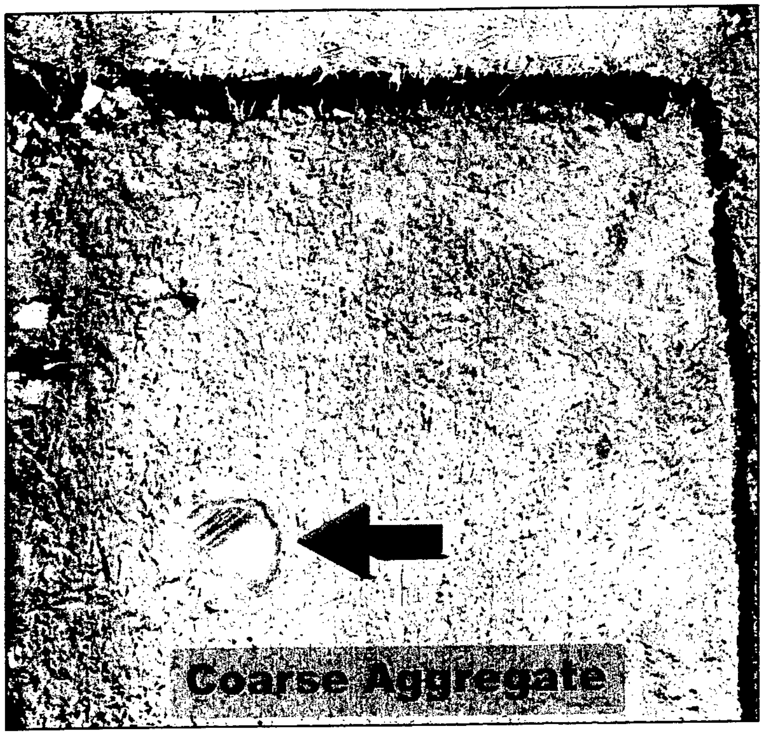


Figure 4-3. Coarse aggregate in 70-lb/ft^3 SACON block.

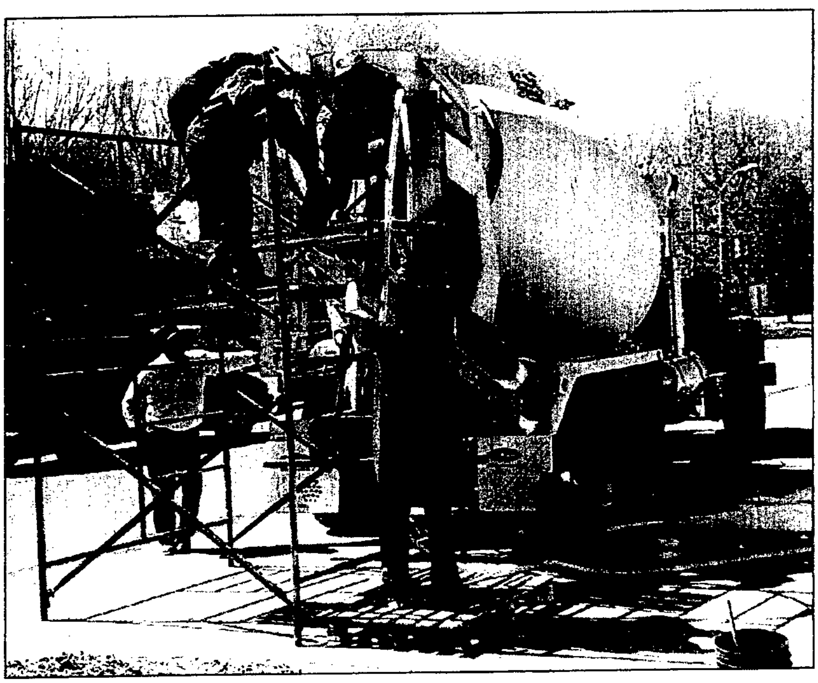


Figure 4-4. Mixing SACON.

A number of specialty mixers designed for mixing cellular concrete for roof deck applications may also be used in preparing SACON. These units have the advantage of being easily portable and capable of mixing both large and small volumes of cellular concrete. Mixers designed for roof deck application are generally equipped with a pump (usually a progressive cavity pump) that is used to convey the fresh concrete to the formwork.

Cellular concretes will generally increase in density when moved with a pump. As the mixture is pumped, density measurements should be made at the point of placement for quality control purposes. The mixture may have to be adjusted to account for pumping distances and special application conditions. Variations in density should be kept under 3 percent.

When SACON is placed, it will typically flow to fill the formwork (fig. 4-5). Placement should be planned so that no lift of SACON is more than 1 meter (3.3 ft) thick. If segregation of the fibers is observed, placement should be suspended until a uniform mixture can be obtained from the mixer.

Figure 4-5. Pouring SACON.

Only minimum consolidation is required to remove any large air bubbles trapped in the mixture. Tapping the sides of the formwork with a rubber mallet is, in general, sufficient to release unwanted air. All formwork used with SACON must be made watertight because of the fluid nature of the mixture. No form-release compounds should be used on the formwork because of a potentially deleterious effect of the compounds on the foam.

The self-leveling characteristics of SACON allow a level surface to be produced on the placed concrete using a screed, as would be done with conventional high-fiber-content concrete. SACON does not generally develop a bleed-water sheen, and finishing can proceed as soon as a level surface is produced.

The best SACON surface finish is developed by the smooth surfaces of the formwork. Producing a smooth finish on the exposed surface of SACON is difficult because of the low density of the concrete and the high fiber content. If an unformed surface must be smooth, the best practice is to grind the surface flat after the concrete has cured.

4.2.2 Range Setup

Electricity is not required to install or operate SACON bullet traps. During site preparation, care should be taken to locate and avoid electrical and other utilities on the range. Site preparation requirements for a 25-Meter Range application are limited to a hard, relatively level surface upon which to place the SACON walls. Excavation is required to protect target coffins on the ARF, AFF, and CPQC ranges. Caution should be taken in disturbing range soils to ensure unexploded ordnance and industrial hygiene issues have been evaluated prior to digging. Disturbing the current range soils may warrant the wearing of PPE to mitigate exposure to lead in the soil (ref 9).

4.2.2.1 USMA West Point Range 3. Range 3 serves as the 25-Meter Range for USMA West Point. Range 3 is located along Route 293, west of West Point near Long Pond. The range is oriented so that the direction of fire is into the side of Listuring Hill.

Range 3 was used to develop performance, costs, safety, logistics, and training realism data. The installation of 90-lb/ft^3 SACON on this range occurred on 8 through 10 April 1997 and was conducted by a team of USMA West Point and WES personnel. Because of rocky soil conditions, it took several hours to prepare the site using a front-end loader (fig. 4-6 and 4-7) (ref 35).

Figure 4-6. Site preparation.

Figure 4-7. Plywood base for walls.

SACON block barriers were installed on four of the range's firing lanes. The barrier walls were constructed using interlocking, I-shaped SACON blocks. The barrier walls were built by stacking blocks immediately behind the target racks. The dimensions of a finished SACON wall were approximately 8 feet wide by 4 feet high by 5 feet deep (fig. 4-9). The blocks were stacked four columns wide by eight or nine rows high by two columns deep. Plywood spacers (1-2/3 in.) were placed under one full block in each of the four columns to offset the block edges (fig. 4-8). The block edges were offset to eliminate any continuous seam through the wall. Each eight-row-high wall was made using a total of 48 full blocks (32 in. long by 24 in. wide by 6 in. high) and 32 half-blocks (16 in. long by 24 in. wide by 6 in. high). The nine block walls consisted of 54 full and 36 half-blocks. The I-shaped blocks were 21 inches wide as measured at the center of the I. Two of the SACON barriers (firing points No. 17 and 18) were constructed from SACON containing polypropylene fibers and the other two (firing points No. 19 and 20) from SACON containing steel fibers. The walls at firing points No. 17 and 19 were enclosed by temporary structures (fig. 4-10). The structures were intended to keep the SACON debris dry to facilitate the bullet containment assessment.

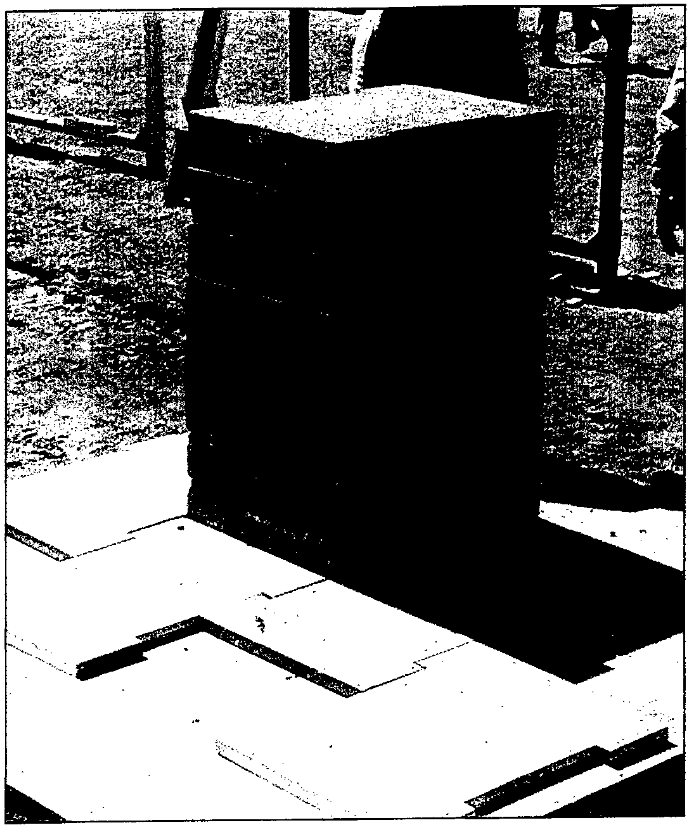


Figure 4-8. SACON wall construction using spacers.

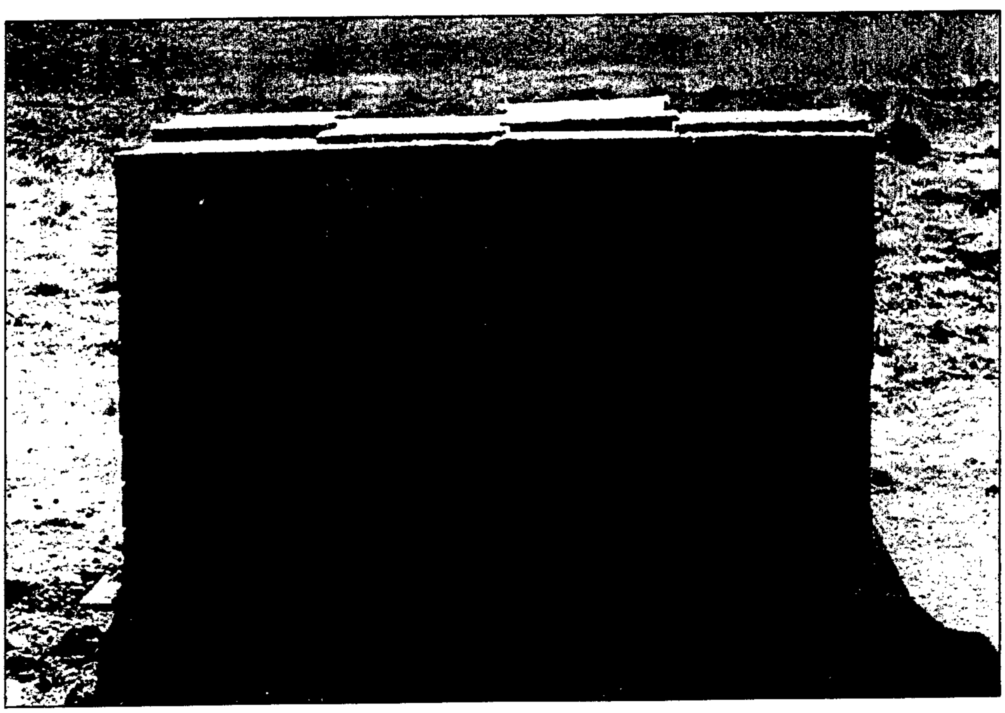


Figure 4-9. SACON wall on USMA West Point 25-Meter Range.

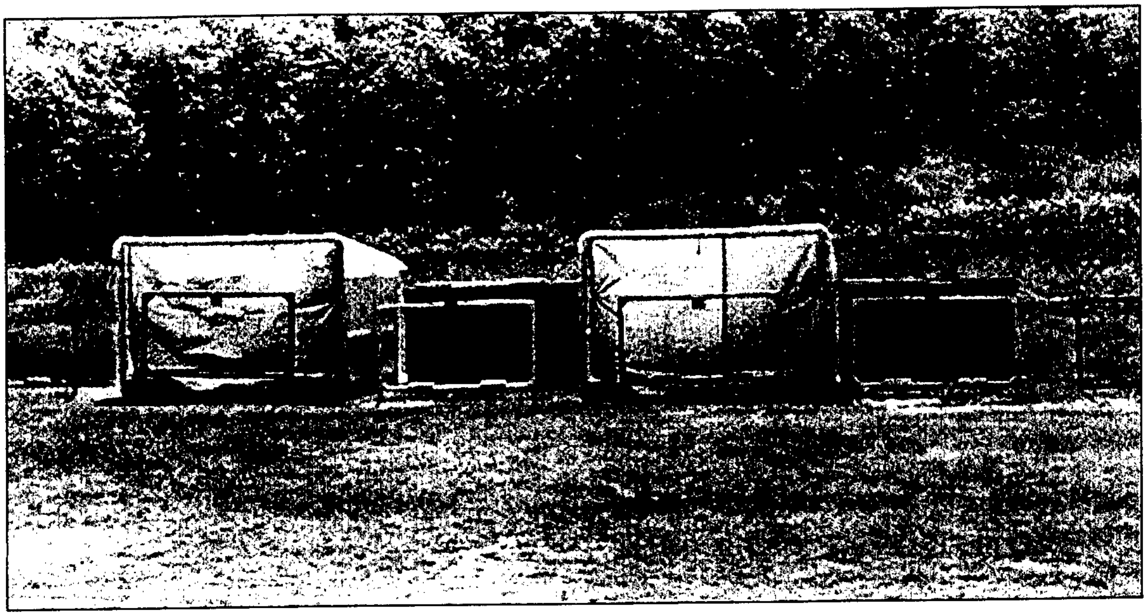


Figure 4-10. USMA West Point firing point temporary structures.

4.2.2.2 USMA West Point Range 5 "Normandy". Range 5 is the automated record-fire range for USMA West Point. Range 5 is located along Route 293, west of West Point near Long Pond. The range is oriented so that the direction of fire is into the side of Listuring Hill (fig. 4-11).

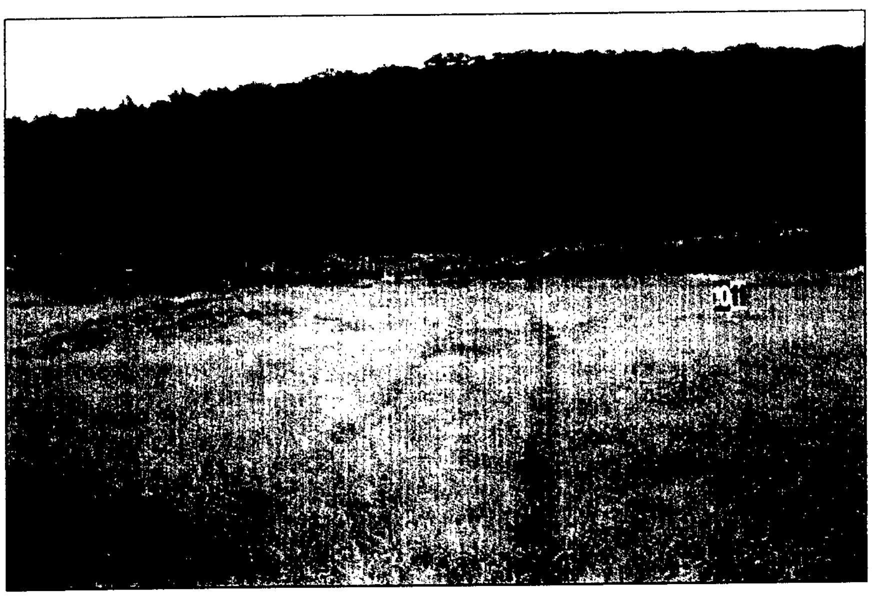


Figure 4-11. Listuring Hill.

USMAWest Point cadets were responsible for the range layout and installation of 90-lb/ft^3 SACON on Range 5. The cadets surveyed the range to determine target positions and impact locations relative to shooting positions. These data were then plotted to determine a typical dispersion of bullet impacts around a given target. Given the bullet trajectories, SACON elements were sized and designed to maximize bullet capture and minimize ricochet potential (ref 36).

SACON was installed on Range 5 by the USMA West Point project team. The project team scheduled range time for emplacement and test firing of the SACON blocks. The team had difficulty in arranging for labor and equipment necessary for the installation, illustrating the necessity of keeping range maintenance requirements to a minimum.

On 27 April 1997, a crew of about 18 cadets worked for 8 hours installing SACON. Equipment used included three 3/4-ton trucks, one multipurpose tractor with a bucket, and an assortment of hand tools. Construction activities included loading blocks onto the trucks, moving the SACON blocks to their planned locations, excavating the existing wooden railroad ties, and preparing the ground for the new SACON blocks (fig. 4-13). A trough behind the lane No. 10 50-meter target position was excavated in preparation for installing the SACON (fig. 4-12).

Figure 4-12. Digging troughs to bury SACON.

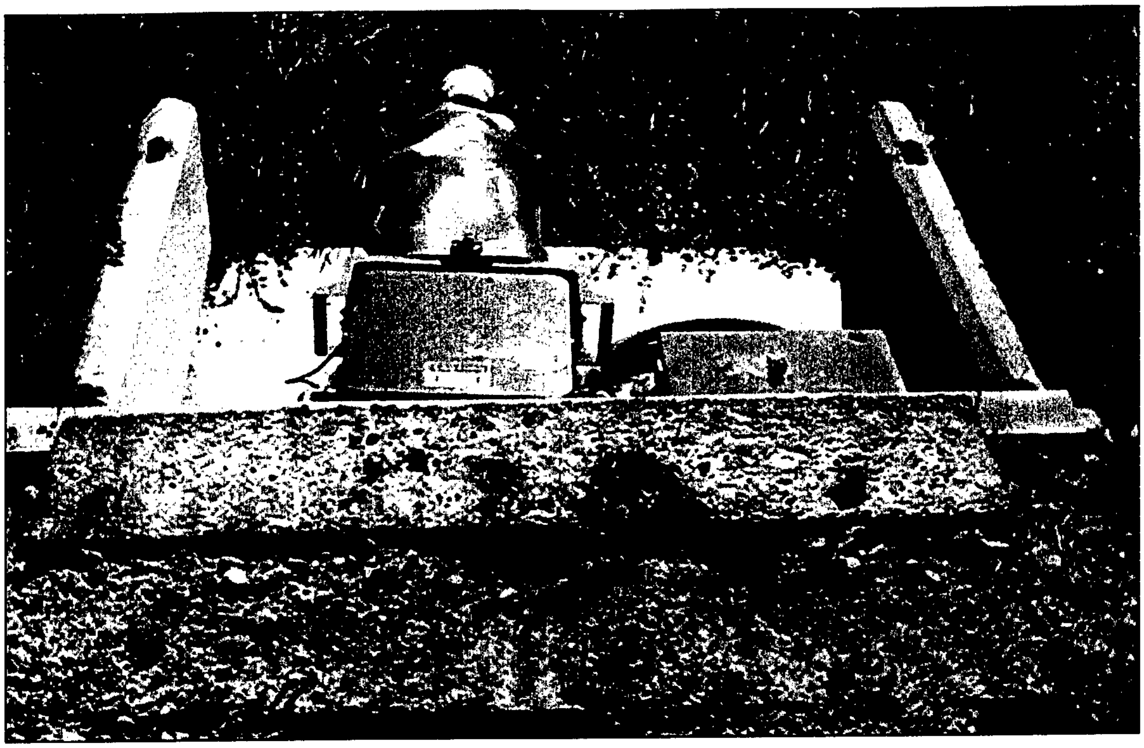


Figure 4-13. SACON blocks protecting target coffin.

Two additional walls were set up, behind the lane No. 2 300-meter target and on the lane No. 6 250-meter target. Workers placed SACON cylinders and blocks on the troughs of the lane No. 9 50-meter targets (fig. 4-14). These cylinders and blocks were arranged so that most of the bullets would hit their vertical face.

Figure 4-14. SACON simulated stumps and rocks.

The problems that arose during installation involved issues of tools and time. The large 2- by 2- by 2-foot blocks of SACON were to be made to look like rocks but the necessary equipment to shape the blocks was not available. An attempt was made to shape them by using picks and shovels. Another delay resulted from a high water table. Water accumulated in trenches that were only 18 inches in depth. Water problems slowed down the digging and prevented completion within 8 hours. A four-cadet crew required an additional 16 hours to complete the emplacement.

4.2.2.3 Fort Knox Canby Hill. The Canby Hill Range serves as a 25-Meter Range at Fort Knox. The Fort Knox 25-Meter Range was used to generate data to support safety, logistics, and training realism assessments.

On 26 through 28 March 1997, a team of five persons installed two SACON walls in approximately 5 hours (ref 35). Approximately 3 of the 5 hours was spent leveling the site for placement of the SACON. Stacking operations were performed using a four-person team to move the blocks: one person at each corner of the blocks. The participants became fatigued during the installation due to the weight of the blocks (greater than 200 pounds).

SACON block walls were installed on firing lanes identified as No. 56 and 57 (fig. 4-15). The dimensions and configuration of the blocks and the resulting walls were the same as described in the West Point 25-Meter Range section. Both walls were exposed to the weather. The barrier on firing lane No. 57 was constructed using SACON containing steel fibers while the barrier on firing lane No. 56 was constructed using SACON containing polypropylene fibers.

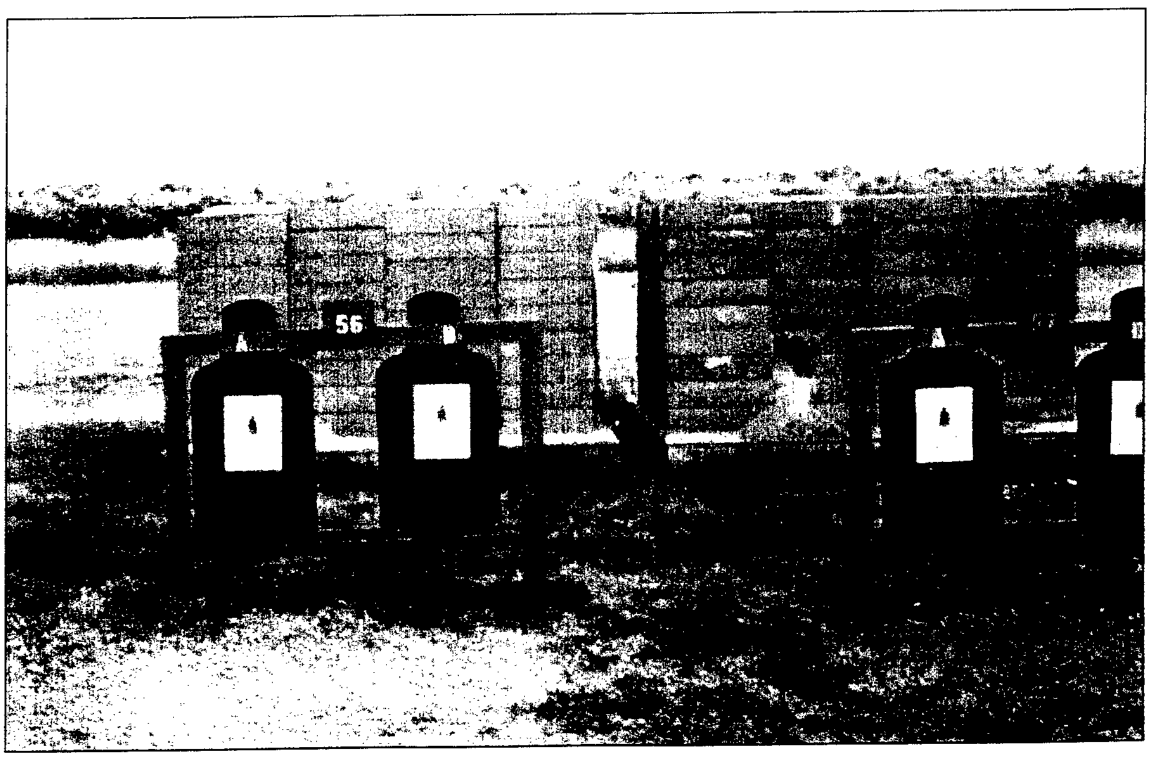


Figure 4-15. Fort Knox Canby Hill Range positions No. 56 and 57.

4.2.2.4 Fort Knox Ditto Range. The Ditto Range is an ARF Range. On 17 June 1997, a total of 13 SACON emplacements (7 target berms (fig. 4-16) and 6 backstops (fig. 4-17 and 4-18)) were installed on firing lane No. 10 (ref 37). Nine to ten SACON blocks (30- by 10- by 6.5-in.) were installed to create each target berm. A combination of SACON blocks and SACON cylinders (either 8 or 12 in. in diameter) was used to make target backstops. The berms were installed to reduce erosion of the soil from the dirt mounds in front of the target coffins and to capture shots that went over or through the target.

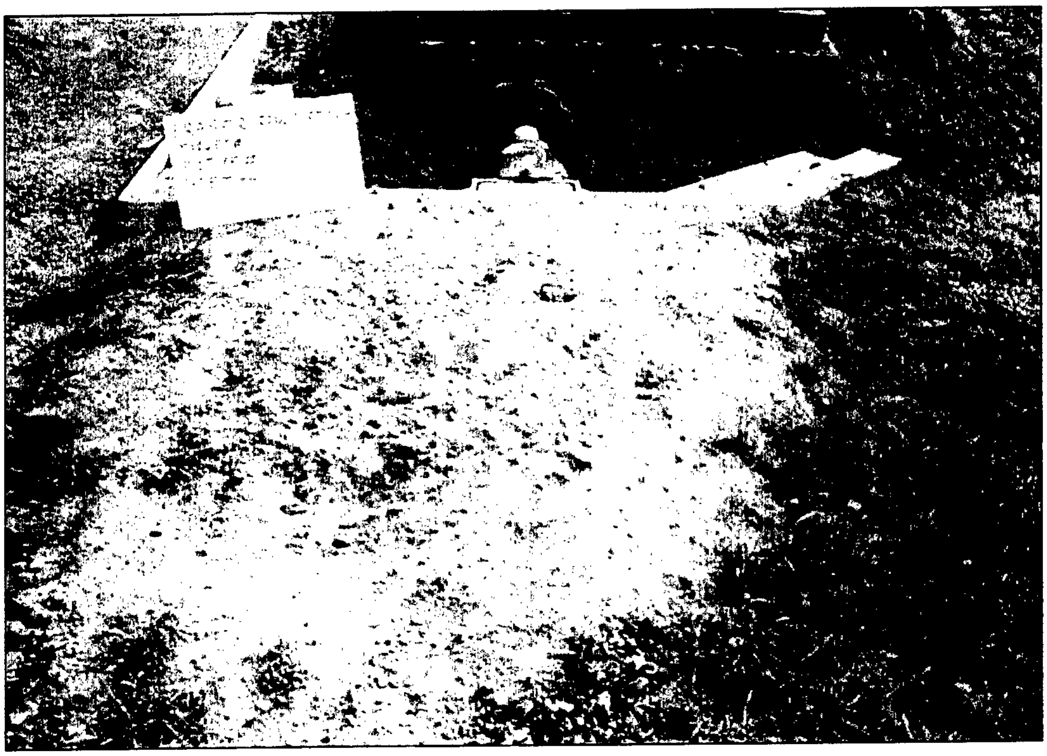


Figure 4-16. Berm, covered SACON in front of target coffin.

Figure 4-17. SACON backstop (block wall, Ditto Range, 50-meter right target, 26 June 1997).

Figure 4-18. SACON "log pile" backstop (Ditto Range, 200-meter target, 26 June 1997).

A front-end loader and all-terrain vehicle were used to move the SACON block to the various emplacement locations. A work crew of four individuals was used to prepare the site and install the SACON items. Site preparation and installation times for the target berms varied from 15 to 20 minutes for each operation. There was little site preparation required for the backstops. Overall, the 13 SACON emplacements were completed in 9 hours.

4.2.2.5 Fort Knox Morgan Range. The Morgan Range is an AFF Range. On 16 June 1997, a total of seven SACON emplacements (three target berms and four backstops) (fig. 4-19) were installed on firing lane No. 15 of the Morgan Range (ref 37). Polypropylene-fiber SACON blocks (30- by 10- by 6.5-in.) were installed on the target berms, and steel and polypropylene-fiber cylinders (either 8 or 12 in. in diameter) were used as target backstops (fig. 4-20). On the 75-, 175-, and 300-meter target berms, the numbers of SACON block ties installed were 32, 22, and 43, respectively.

Figure 4-19. SACON buried in berm in front of target coffin, Morgan Range.

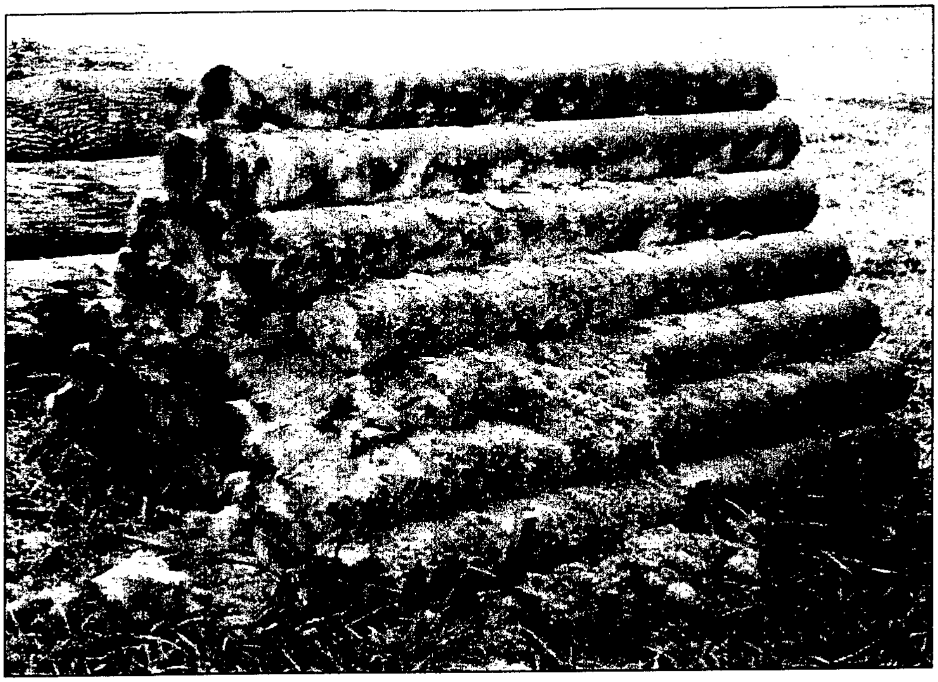


Figure 4-20. SACON simulated log backstop after firing, Morgan Range.

A truck was used to stage the SACON block into position on the range. On the average, a work crew of four individuals was used to prepare the site and install the SACON items. Depending on the SACON emplacement, site preparation and installation times for the target berms varied from 85 to 185 minutes. There was little site preparation required for the backstops. In all cases, no more than 30 minutes were needed to install each SACON log backstop. Overall, the seven SACON emplacements were completed in 7 hours.

4.2.2.6 Fort Knox Fraser Range. Fraser Range is a CPQC-type range. On 25 June 1998, a total of 11 polypropylene-fiber SACON emplacements were installed on firing lane No. 7 (fig. 4-24) (ref 37). The SACON items were either 18- by 18- by 6.5-inch or 30- by 10- by 6.5-inch blocks. The blocks were installed on the seven target berms (fig. 4-21) and behind four target positions as backstops (fig. 4-22 and 4-23).

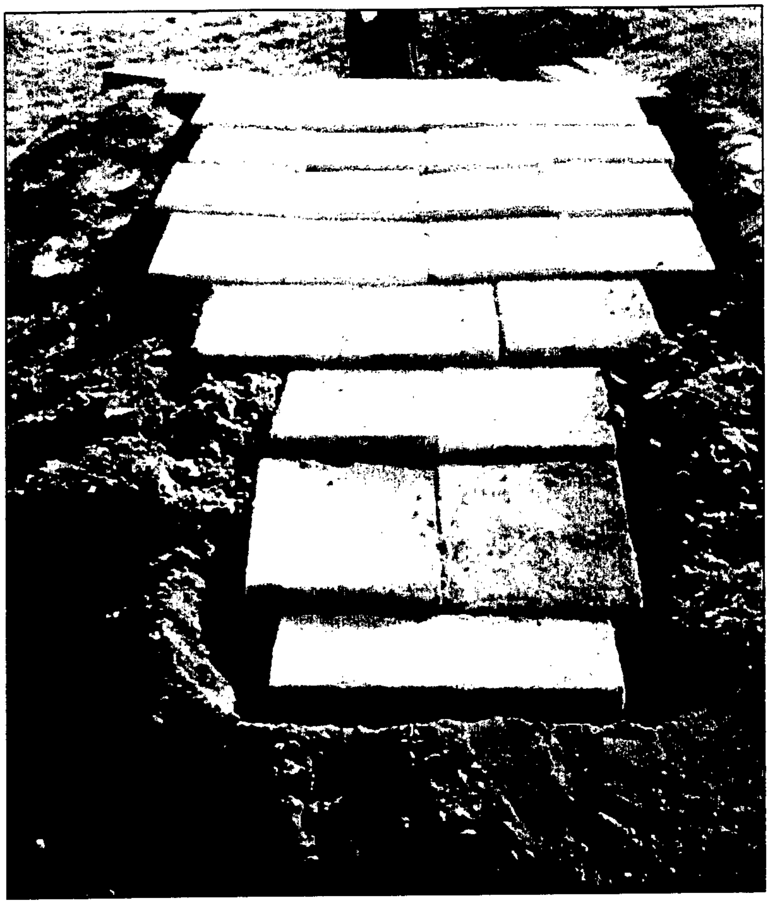


Figure 4-21. Berm (soil cover not installed), Fraser Range.

Figure 4-22. Camouflaged SACON railroad ties protecting target coffin.

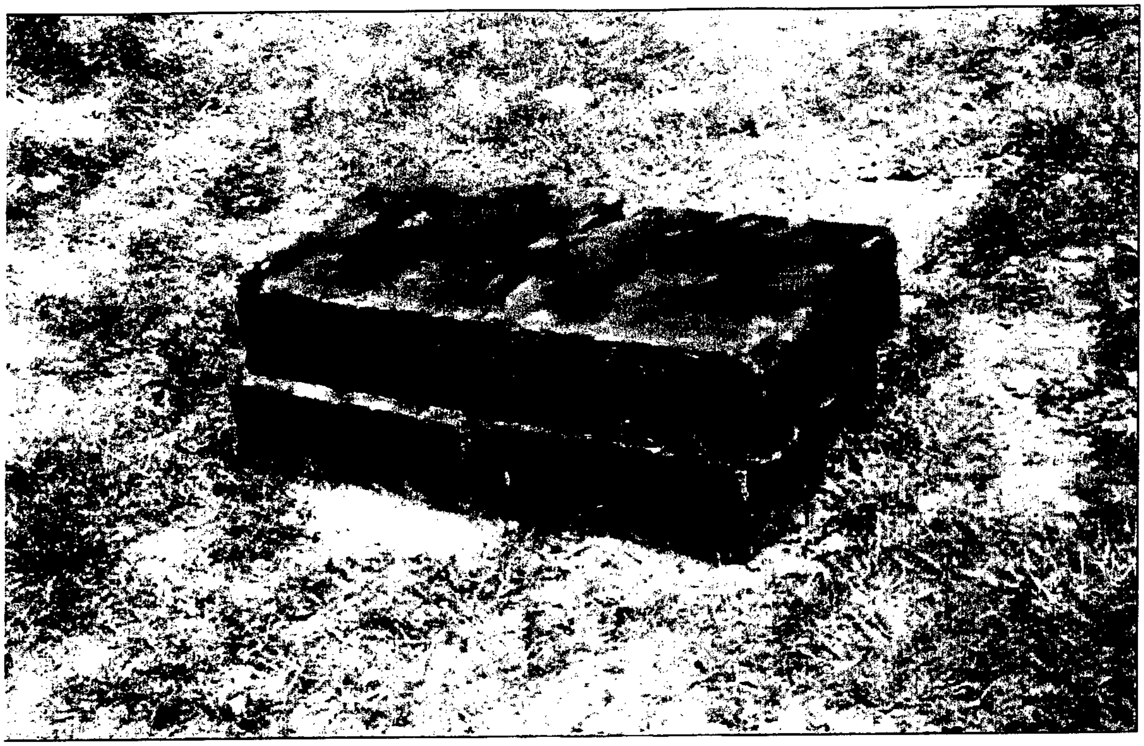


Figure 4-23. Camouflaged SACON backstop.

A work crew of four persons dug out all SACON emplacements by hand. Because of the target configuration and existing underground electrical power, it was not practical to use heavy equipment. However, a rough-terrain bucket loader and an all-terrain vehicle were used on a path adjacent to the firing lane to stage the SACON items. Site preparation and SACON installation times varied from 5 to 50 minutes. Overall, the 11 SACON emplacements were completed in 5 hours.

Figure 4-24. Fraser Range overview - before SACON.

4.2.2.7 ATC Michaelsville Range 22. Michaelsville Range 22 is an ATC range used for testing small-arms weapons and ammunition. Michaelsville Range 22 was set up to simulate a 25-Meter Range for an accelerated SACON durability test with an accelerated firing rate (ref 10). The accelerated durability test produced performance, cost, safety, and logistics data. The installation of three SACON walls was completed in 6 hours. The installation team consisted of six persons and utilized a forklift in placing the blocks. Two members of the team manipulated the blocks from the forklift.

Three separate block walls were built on this range, using three SACON variants: recycled, reformulated, and large block (fig. 4-25). Comparisons were made between the performance of recycled SACON and that of reformulated SACON. Comparisons were also made between the I-shaped SACON block and a larger cube shape.

Figure 4-25. ATC test walls.

The first wall (recycled block) consisted of I-shaped blocks of recycled SACON. The wall was constructed upon an asphalt surface with the blocks placed on eight pallets configured two high, two wide, and two deep. The recycled block wall was made using a total of 32 full blocks and 32 half-blocks. The blocks were stacked three columns wide by eight rows high by two columns deep. Plywood spacers were placed under one full block in each of the three columns to offset the block edges. The elimination of block edges was done to prevent a continuous edge path through the wall depth. The second wall (reformulated block) contained the same number of blocks and was constructed in the same manner as the recycled block wall. The third wall (large reformulated block) was made from two reformulated SACON cubes with a nominal measurement of 24 inches on a side. Each cube was placed upon a stack consisting of a pallet and 12 I-shaped SACON blocks (two columns wide, two columns deep, and three rows high). The bottom of the cubes was raised to a height of 24-1/2 inches to develop a 90° angle between the line-of-fire and the wall face (fig. 4-26).

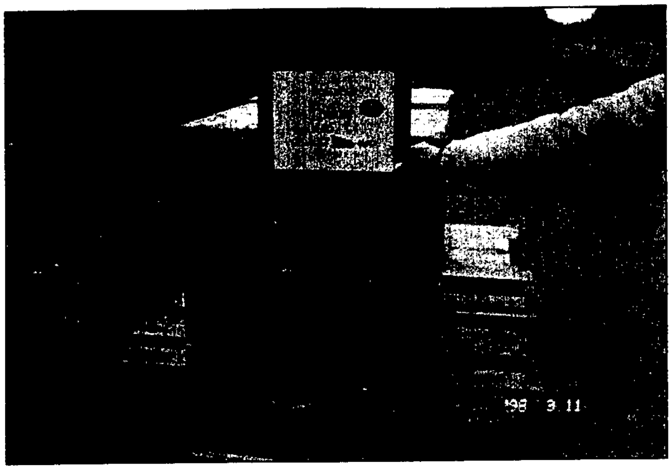


Figure 4-26. Large block.

4.2.2.8 ATC Trench Warfare Range. ATC's Trench Warfare Range is an instrumented range used for fire control and ammunition testing. The range was utilized to collect ricochet data necessary for the development of an SDZ. Instrumented testing was conducted by firing 5.56-mm (M855 and M193), 9-mm (M882), and .45-caliber (M1911) at SACON from several "flat" angles. The impact and exit angles and velocities as well as ricochet distances were recorded (ref 10).

4.2.2.9 WES Facility. WES produced the SACON and the recycled SACON used in the demonstration at their Concrete Structures Laboratory in Vicksburg, Mississippi. Costs associated with the manufacture and recycling of SACON were assessed based upon this production. Manufacturing and recycling operational descriptions are provided in Sections 4.2.1 and 4.2.3.

4.2.3 Range Operation

Normal training operations were conducted at Fort Knox and USMA West Point during the demonstration period. An accelerated firing schedule was utilized at ATC.

4.2.4 Recycling Operations

4.2.4.1 Overview. A recycling operation was conducted to generate data to evaluate the WES SACON recycling process and the end product. The recycling operation produced new SACON barrier blocks from used blocks that contained bullets and bullet fragments. WES developed the unit processes required for recycling SACON in a fashion to minimize special equipment and labor requirements and to provide adequate safety precautions for the conduct of recycling operations.

The recycling demonstration was designed to develop approximately 5,000 pounds of fine aggregate (sand) that could be reused in the formulation of recycled blocks. The aggregate was combined with fresh cement, foam, stabilizer, water, and fiber to form approximately 10,000 pounds of new SACON. WES conducted the recycling demonstration at its Vicksburg facility using WES-owned and -operated equipment.

4.2.4.2 Description of Recycling Unit Processes and Operations (ref 10).

4.2.4.2.1 Sorting. For the purpose of this initial processing of SACON, blocks known to contain bullet fragments were separated from blocks that had no bullet fragments. (Note: Typically, only blocks containing bullet fragments would be recycled; however, an adequate volume of lead-contaminated blocks was not available to provide the volume of fine aggregate desired for casting the reformulated SACON blocks. Because of this, uncontaminated blocks were crushed to generate the desired volume of aggregate. The crushing, separating, and sieving processes for the contaminated blocks were conducted separately from those for the uncontaminated blocks. Sorting was performed only for this purpose and was not considered to be a routine step in the recycling process.) Sorting was done by visually inspecting blocks for bullet damage. Undamaged blocks were palletized and stacked (fig. 4-28). Fractured material was collected in open-topped 200-liter steel drums with clamp-style lids (fig. 4-27). SACON used in this demonstration included both the steel-fiber-reinforced and the polypropylene-fiber-reinforced material. A variety of pigmented and unpigmented samples were processed together.

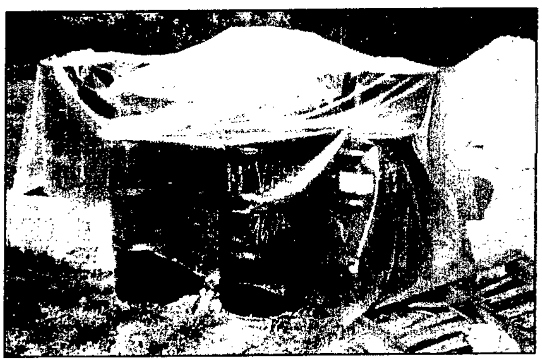


Figure 4-27. Sorted, used SACON blocks.

Figure 4-28. Palletized SACON.

4.2.4.2.2 Storage and transportation. SACON blocks that were exposed to live fire were fragmented and required storage in containers. Open-topped steel drums equipped with lids and clamped hoops were the most secure methods of storage (fig. 4-27). SACON blocks that had not been involved in testing were intact and could be labeled and palletized (fig. 4-29).

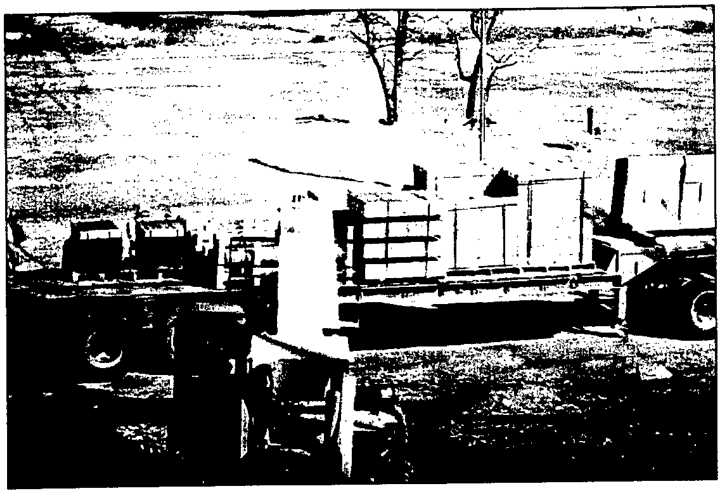


Figure 4-29. Transporting SACON.

4.2.4.2.3 Breaking. A portion of the SACON blocks recycled was in the form of large block fragments. The SACON blocks had to be reduced to fragments approximately 6 inches in size to be acceptable for crushing operations. Fragments with lengths greater than 6 inches were difficult to crush in the next unit process. The blocks were reduced to the 6-inch size using a jackhammer (fig. 4-30).

Figure 4-30. Breaking SACON.

All personnel in the area were equipped with disposable coveralls, boot covers, rubber gloves, and properly fitted respirators equipped with HEPA filter cartridges during all recycling processes (fig. 4-31 and 4-32). A WES safety representative inspected the operation prior to startup and monitored air quality.

Figure 4-31. PPE.

Figure 4-32. PPE.

4.2.4.2.4 Crushing. Crushing was performed by passing a steel-wheeled paving roller over SACON fragments that were placed in plastic-lined fabric bags (fig. 4-33). Plastic (6-mil polyethylene) sheeting was placed within the bags to prevent the release of dust. The bags were placed over a 5- by 15-meter concrete slab. Two wooden ramps made from 4- by 4-inch lumber were used to place the roller on the bags. The steel roller made enough passes over the bags to reduce the used concrete (fig. 4-34) to fragments smaller than 9 mm (fig. 4-35).

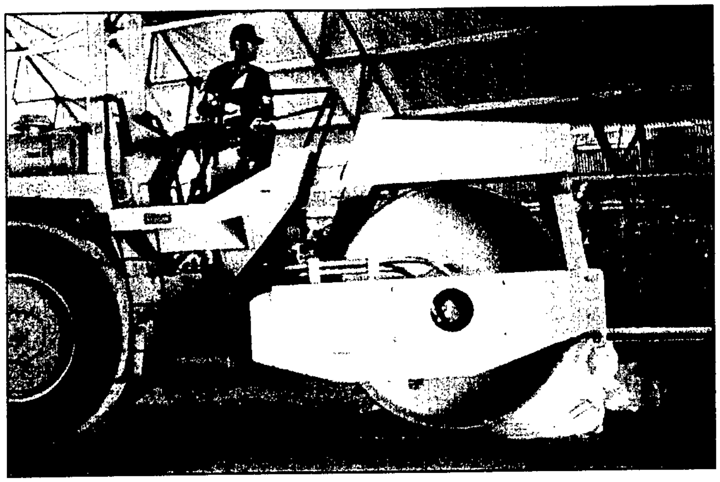


Figure 4-33. Crushing SACON.

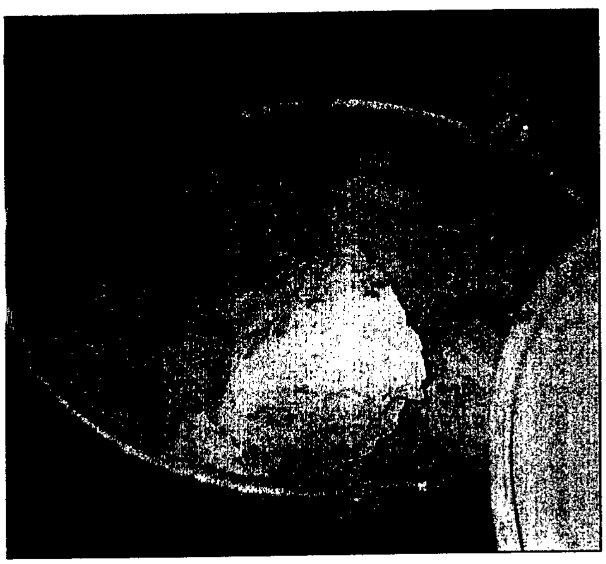


Figure 4-34. Before crushing.

Figure 4-35. After crushing.

Prior to performing crushing operations, WES tested the crushing area to determine the background content for lead. The WES repeated this testing after the crushing of the contaminated SACON was completed and the area had been cleaned. WES monitored air quality during the crushing processes. Air samples were taken of the general area and from the worker's breathing zone. The samples were analyzed for particulate and lead dust concentrations.

WES collected a composite sample of the crushed, contaminated SACON for total metals (lead) and TCLP analysis. This established a baseline for assessing metals removal efficiency.

The crushed material was transported to the separation process in the bags. After the crushed material was removed from the fabric cover, the fabric cover (or bags) was sampled for lead and TCLP and disposed of as required by the analysis results.

4.2.4.2.5 Magnetic separation. Steel fragments introduced by the use of steel fibers and from the M855's penetrators were collected magnetically using a bar magnet located across the sieve inlet (fig. 4-36). The magnetic separation was conducted as the material entered the sieving process. The metal fragments were transported by a conveyor belt to a metal pan. WES weighed the metal fragments removed from the contaminated, crushed SACON. The metal fragments removed from the contaminated, crushed SACON were sampled and tested for lead content and TCLP analysis. The material was disposed of as required by environmental regulations.

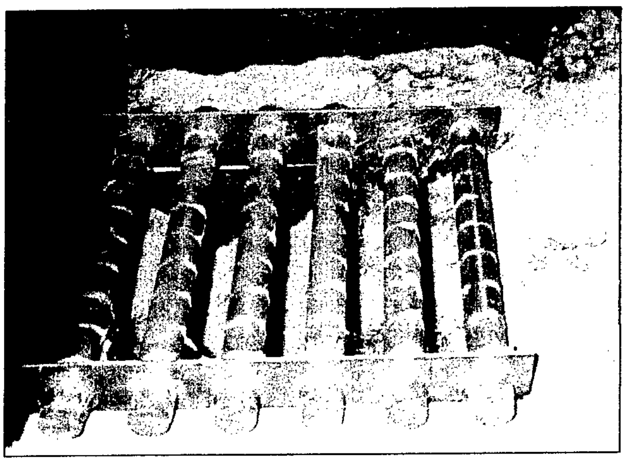


Figure 4-36. Bar magnet.

4.2.4.2.6 Sieving. The crushed, magnetically cleaned SACON was sieved using a vibrating sieving system (fig. 4-37). This type of unit holds the sieve series in an enclosed cabinet that is maintained under negative pressure. A cyclone dust collector equipped with a 200-liter dust collection drum and a polyester-felt dust bag produced the negative pressure. This type of filter can handle volumes of air up to 38 m^3/min (1400 cfm of air) and is designed to remove 99.5 percent of particles as small as 1 micron. Air exhausted from the dust collector was drawn into a second cyclone cleaner that exhausts air from the equipment bay housing the sieve system.

Figure 4-37. Separating sieve fractions.

The contaminated and uncontaminated crushed SACON was sieved separately. During contaminated SACON sieving, bullet fragments larger than 9 mm were separated from the crushed SACON. Bullet fragments smaller than 9 mm were included in the aggregate mix that was used in reformulating the SACON. WES weighed the dust collected in the cyclone cleaner filters, and a composite sample was collected and analyzed for lead content and TCLP. The dust was disposed of as required by environmental regulations. Also, WES collected samples from surfaces in and around the sieving equipment. These samples were analyzed for lead content. Sampling was not conducted on the dust generated during sieving of the uncontaminated, crushed SACON.

4.2.4.2.7 Blending. The sieve fraction collected was reconstituted to form a fine aggregate that had a size distribution compatible with the requirements given in the Technical Specification for SACON (ref 10). The fine aggregate was weighed and a composite sample was collected by WES and analyzed for lead content and TCLP. (Note: Lead analysis and TCLP were conducted only on the aggregate collected from the contaminated, crushed SACON sieving.)

All personnel in the vicinity of the sieving system were outfitted with disposable coveralls, boot covers, gloves, and an individually fitted respirator equipped with HEPA filters. The air was monitored in both the equipment bay and the respiratory zone of individual workers.

4.2.4.2.8 Remixing. The sieved fractions from both the contaminated and uncontaminated crushed SACON were combined and used to make the new SACON blocks. All materials not passing through the No. 4 and 100 sieves were discarded. (Prior to combining the contaminated and uncontaminated, crushed SACON, WES collected a sample of the contaminated, crushed SACON and made test cylinders of recycled SACON in the laboratory. This recycled SACON was sampled and tested for lead and TCLP analysis.) The combined aggregate was added to a cleaned commercial transit mixer (fig. 4-38). The transit mixer contained clean water proportioned for mixing and produced a water-sand slurry that did not cause any dust dispersal. The additional components needed for the concrete were weighed and added to the mixer. The proportions of material followed the formulation presented in Table 2-1. The amounts of material used were such as to produce approximately 7.6 m^3 (10 yd^3) of polypropylene-fiber-reinforced SACON.

Figure 4-38. Mixing in recycled aggregate.

4.2.4.2.9 Casting and curing. The fresh SACON mixture was placed in individual block molds to produce approximately 30 blocks for the 25-Meter Range bullet barrier walls (fig. 4-39). Additional specimens were collected for testing to determine unconfined compressive strength (ref 38) and modulus of rupture (ref 39). The results of these tests were compared to the results of tests performed on original SACON formulations.

Figure 4-39. Molding SACON.

A clear silicate or latex-curing compound was applied to the exposed concrete surface. The blocks were allowed to cure in the molds for 28 days prior to demolding.

4.2.4.2.10 Demolding and transportation. After 28 days of curing, the recycled blocks were demolded and inspected. All blocks were marked with serial numbers and labeled as recycled. The recycled blocks were palletized and transported to ATC for testing on a 25-Meter Range.

4.2.5 Data Acquisition

4.2.5.1 A **three-tier** approach to data acquisition, illustrated in Figure 4-40, was used.

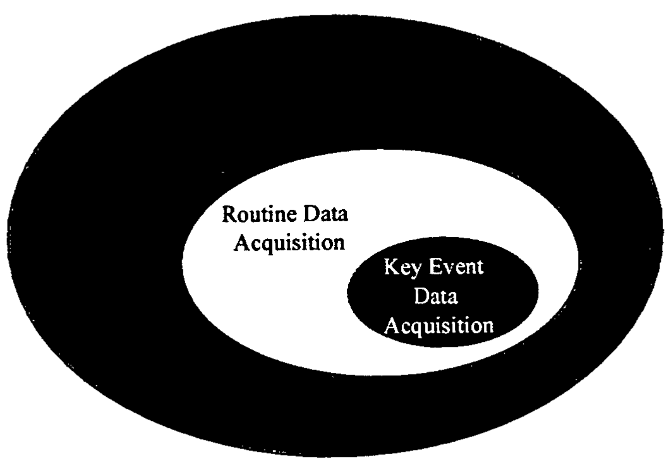


Figure 4-40. Data acquisition approach.

4.2.5.2 The **first tier** consisted of active participation by Defense Evaluation Support Activity (DESA), ATC, or WES during selected key demonstration events. DESA was present during installation of the SACON barriers at both range locations and during the casting of all SACON materials. In addition, the DESA collected baseline soil samples around the SACON barriers installed on two firing lanes at West Point for the environmental compatibility assessment, and monitored the overall data collection effort during their bimonthly monitoring visits to USMA West Point and Fort Knox. The ATC collected the post-demonstration soil samples at USMA and completed several monthly range inspections at USMA and Fort Knox. The WES conducted a recycling operation for assessment by ATC. The ATC conducted durability, ricochet, and leachability testing to fill data gaps. The ATC obtained the laboratory test results from the predemonstration soil samples taken at USMA as well as partially completing technology performance sampling results. The ATC collected and analyzed the post-demonstration soil samples from USMA. In addition, ATC supplemented the evaluation survey and manual data collection forms with photographs and video recordings of the demonstration. These recordings were used to characterize impact erosion and target protection and to supplement the maintainability, durability, and safety assessment of the SACON barriers.

WES personnel recorded objective and subjective data for use in evaluating the manufacturing and recycling of SACON. Objective data collected included waste characterizations, industrial hygiene sampling, weights, etc. Subjective data were provided for cost evaluation purposes. The WES provided their manufacturing and delivery costs associated with the manufacture of SACON and estimated private manufacturing costs. Costs associated with extracting metals from the SACON debris, metal reclamation credits, and disposal of residue debris were also collected. The WES videotaped the recycling operation to supplement the safety evaluation.

4.2.5.3 Because resource limitations precluded DESA's/ATC's active participation in day-to-day firing operations at the ranges, the **second tier** of data was collected by range personnel. Second-tier data included environmental and technology performance sampling of the debris in front of the two SACON barriers at USMA, a monthly assessment of SACON block durability and maintainability by range operators, and a daily recording of rounds fired on SACON-equipped firing lanes. Data collection gaps necessitated additional controlled durability and technology performance tests to be conducted by and at ATC as part of the first tier.

4.2.5.4 **Third-tier** data were obtained through literature reviews and other research on cost, safety, maintainability, and training realism information not obtainable through observation. The majority of this data was obtained from AEC and WES publications or through interviews with installation Range Managers.

4.3 Test and Evaluation Procedures

4.3.1 Performance Objectives

4.3.1.1 Objective 1-1.

4.3.1.1.1 Test Procedure. The objective was to determine the efficiency of SACON in capturing incoming rounds. Firing points No. 17 and 19 on USMA's Range 3 were to be used to generate data for this assessment. The walls were set up on the 25-Meter Range as described in Section 4.2.2.1. Plastic pans were placed immediately in front of the walls to capture falling debris. Regular inspections were to be made and documented using the USMA Barrier/ Container Inspection Data Form. Occurrences in which debris was not contained were to be reported on Part D of the form. The number of rounds fired on each lane was collected on the USMA Firing Unit Data Form.

At scheduled intervals (ref 9), the debris was to be removed from the catch pan, packaged, and sent to a laboratory for analysis. The analysis was to consist of a total weight of the debris and a composite lead concentration of the debris (ref 40).

Unfortunately, the weights of the debris generated at USMA's firing points No. 17 and 19 were not collected. The data (mass of debris, total lead concentration in the debris, and the number of rounds fired) to support the assessment of this objective were generated at ATC as a by-product of the accelerated durability test (ref 10). Metal containment efficiency was derived from the debris collected during durability testing at ATC. At the conclusion of durability testing, the weight of the debris was determined. Composite samples were taken of the debris material. The composite samples were delivered to ATC's Chemistry Laboratory for analysis. The laboratory crushed the material in an attempt to achieve homogeneity. Large fragments were removed using a No. 10 sieve with a 2.00-mm opening. The amount of lead removed by the sieve was calculated by the Energy Dispersion X-ray Spectroscopy (EDX) Method (ref 41).

The material that passed through the sieve was analyzed, using the trace Inductively Coupled Plasma (ICP) - Atomic Emission Spectroscopy Method (ref 40) to measure total lead concentration in the debris.

4.3.1.1.2 Evaluation Procedure. The concentration determined by the EDX Method was added to the concentration determined by the ICP Method. The resultant total lead concentration was then converted into a total amount of lead in the debris by multiplying the lead concentration by the mass of the debris. The total mass of lead in the debris was divided by the mass of lead in an M855 slug to determine the number of bullets not contained by the SACON wall. The M855 slug contains 32.00 grains of a lead-antimony alloy (ref 42). The percentage of antimony varies from 1.0 to 2.5 (ref 43). For calculations, an antimony percentage of 1.75 was used, which yielded a lead content of 31.44 grains per M855 bullet slug. The method for calculating containment efficiency is presented in Figure 4-41.

Given:
32.00 grain lead/antimony alloy per M855 bullet.
Average antimony content in alloy = 1.75 percent.
6.479891×10^{-5} kilograms per grain (ref CRC Handbook).

Calculate total lead (Pb) collected in the debris pile:

(Mass debris, kg) x (Debris Pb concentration, mg/kg) x (kg/1000mg) = (Pb mass lost, kg)

Convert total lead to an estimated number of M855 bullets:

(Pb mass lost, kg) x (M855 /31.44 grain Pb) x (grain)/6.479891×10^{-5} kg = (No. of M855 bullets)

Determine percentage of bullets retained by SACON wall:

$$\frac{\text{(Number of rounds fired) - (Number of bullets not retained)}}{\text{(Number of rounds fired)}} \times 100 = \%\ \text{Captured}$$

Figure 4-41. Containment efficiency calculation method.

4.3.1.2 Objective 1-2.

4.3.1.2.1 Test Procedure. The objective was to determine if the debris from the SACON blocks was a RCRA hazardous waste, based on the characteristics of toxicity. Wastes exhibiting toxicity characteristics are those that leach constituents above the regulatory limit listed in 40 CFR 261.24 (ref 44). The waste classification of SACON debris is dependent upon the amount of leachable lead present in the waste material. If the collected waste debris contains leachable lead in concentrations meeting or exceeding the regulatory limit of 5 ppm, it will be characterized as a RCRA hazardous waste. The method used to assist in this determination is the TCLP, EPA Method 1311 (ref 15). Samples were taken from debris piles and wall cavities at USMA, Fort Knox, and ATC. The debris pile and cavity samples were considered to provide a worst case for lead contamination. These samples were analyzed for leachable lead content using the TCLP method.

4.3.1.2.2 Evaluation Procedure. The TCLP analytical data were reviewed to determine if the 5-ppm leachable lead limit was exceeded. Any measurement that exceeded the 5-ppm level constituted a failure.

4.3.1.3 Objectives 1-3 and 1-4.

4.3.1.3.1 Test Procedure. The objective was to assess the effect of SACON bullet traps on range soil erosion and target protection. Range Inspection Surveys and Installation Range Manager Inspection Surveys were completed by maintenance personnel performing the periodic inspections. These surveys were designed to elicit inspector responses to determine whether the SACON blocks and barriers were perceived to reduce the amount of erosion and improved target protection as compared to non-SACON-enhanced ranges. Photographs and video recordings were used to supplement the range surveys.

4.3.1.3.2 Evaluation Procedure. A subjective evaluation was made based upon the survey responses and photograph documentation.

4.3.2 Costs

4.3.2.1 Objective 2-1.

4.3.2.1.1 Test Procedure. The objective was to determine the nonrecurring cost associated with using SACON bullet traps. An estimate of the nonrecurring (capital) costs associated with SACON was derived for a typical barrier installed on a 25-Meter Range. The cost data to support the estimate were generated during manufacture, transportation, site preparation, and installation activities. Site preparation and installation costs were based on labor hours expended in performing these tasks. Actual manufacturing costs were obtained from WES. Transportation cost data collected were those expended to move the SACON from the manufacturer (WES) to Fort Knox, to USMA, and to ATC.

4.3.2.1.2 Evaluation Procedure. The capital cost for a typical 25-Meter Range SACON barrier was determined by adding the manufacturing, transportation, site preparation, and installation costs. The capital cost for a 20-lane, 25-Meter Range was extrapolated from the single-lane cost.

4.3.2.2 Objective 2-2.

Test Procedure. The objective was to determine the recurring cost associated with using SACON bullet traps. An estimate of the recurring costs was derived for a typical barrier installed on a 25-Meter Range. The recurring costs were determined by adding the costs of maintaining, remanufacturing, and disposing of SACON. For the 25-Meter Ranges, maintenance costs were based on barrier refurbishment activities.

Evaluation Procedure. The cost of each maintenance task was calculated by multiplying the number of man-hours utilized by the appropriate labor rates. The capital cost for a 20-lane, 25-Meter Range was extrapolated from the single-lane cost.

4.3.3 Safety

4.3.3.1 Objective 3.1.

Test Procedure. The objective was to determine if SACON bullet traps produced ricochets. Initially, the assessment was to be based upon the field demonstrations at USMA and Fort Knox. The safety record for SACON as used on the Fort Knox and USMA small-arms ranges was to be carefully documented. Fort Knox and USMA range personnel performed periodic inspections of the SACON barriers on the 25-Meter Ranges to determine if any ricochets had occurred. Observed or suspected ricochets were documented on the Inspection Data Form. ATC viewed this methodology as inadequate to assess the objective and produced supplemental test data. An instrumented approach was taken at ATC. Ricochet angles, velocities, and distances of two rifle and two pistol rounds (.45-caliber pistol round (M1911), 9-mm pistol round (M882), and the M16 rifle rounds (M855 and M193)) were measured after impacting SACON blocks. The initial impact angle for SACON ricochet testing was set at 2° and increased at 2° increments until a total of seven angles were achieved.

Evaluation Procedure. The data generated at Fort Knox and USMA were analyzed by determining the number of ricochets by SACON type and by range location. If any ricochets were noted, the firing angle of incidence was compared to the test data generated at ATC for validation.

The data processed by ATC included the impact and exit velocities, angle results, and distances. All data were processed using the Weibel 1000 processor and parallax program. If the round broke up into several pieces, the piece with the highest velocity was processed with no reduction in projectile weight. This provided the worst-case scenario and, therefore, the largest ricochet distance.

The data were used by the COE Engineering and Support Center (ESC), Huntsville, Alabama, to assess the impact on the respective safety fans created by installing SACON on the 25-Meter, ARF, AFF, and CPQC Ranges. The ricochet distance and angle were compared to the SDZ for small arms published in AR 385-64 (ref 45). The results of the tests, after evaluation of test data by CE ESC, were sent to the U.S. Army Training and Doctrine Command (TRADOC), Range Safety Program Manager, for certification to use SACON blocks on a range if the blocks do not increase the safety fan.

4.3.3.2 Objective 3.2.

Test Procedure. The objective was to assess personnel safety during SACON barrier installation and maintenance. On the 25-Meter Ranges, it was envisioned that personnel unaided by mechanical equipment could unstack and restack the SACON blocks when the barrier required refurbishment. A Range Supervisor administered a survey to personnel conducting a barrier refurbishment to aid in assessing selected safety issues. Accidents or injuries related to SACON barrier refurbishment were also to be recorded on the survey by the Range Supervisor. These surveys were to be supplemented with photographs/video recordings of the barrier refurbishment.

Air monitors were used to sample the breathing zone of the workers to determine particulate and lead exposure levels during barrier refurbishment and removal activities.

Evaluation Procedure. An assessment was performed, from a personnel safety perspective, regarding the procedures employed during barrier refurbishment. This assessment started by comparing SACON block weight to weight restrictions on manpower lifting to determine the minimum number of personnel required to safely lift the blocks (ref 46). The particulate and lead exposure levels were compared to Occupational Safety and Health Administration (OSHA) 29 CFR 1910 (ref 47) to determine appropriate PPE for maintenance activities.

4.3.4 Logistics

4.3.4.1 Objective 4.1.

Test Procedure. The objective was to assess the maintainability of the SACON bullet traps. At USMA and Fort Knox, range personnel conducted periodic SACON barrier inspections and recorded their observations. Maintenance actions were initiated by the Range Manager when the barrier was penetrated to a depth equal to or greater than 42 inches (66 percent of thickness). The time required to refurbish the SACON barriers was recorded. Maintenance personnel tasked with unstacking and restacking the SACON blocks completed a Maintainability Survey to record their opinions regarding the ease of handling these blocks. On the AFF, ARF, and CPQC Ranges, designated range personnel inspected and performed periodic maintenance. These SACON configurations were not to be replaced during the evaluation period; however, maintenance personnel were to record time spent maintaining each target.

Evaluation Procedure. It was envisioned that personnel unaided by mechanical equipment could install and maintain SACON barriers. The results of the personnel safety analysis (section 4.3.3b) were reviewed to determine what type of equipment was required to install and maintain SACON in a safe manner. The survey responses concerning maintainability were summarized and converted into a listing of recommended equipment. The list included equipment generally accessible to range personnel. Specialized equipment requirements were identified.

4.3.4.2 Objective 4.2.

Test Procedure. The objective was to assess the durability of the SACON bullet traps. Durability was characterized by correlating bullet penetration depth in the SACON barrier blocks to the number of rounds fired. Depth-of-penetration measurements, round counts, and observations were made at the Fort Knox and USMA 25-Meter Ranges. Unfortunately, round counts could not be correlated to the individual cavities. Cavities develop as a result of concentrated round impacts directly behind the target placement on the 25-Meter Range. The cavity sections of the wall are the portions of the wall that reach failure and require maintenance first. Additional data were generated to correlate the number of rounds fired to the depth of penetration within a cavity. Observations at USMA and Fort Knox indicated a typical cavity from a single firing lane could be approximated roughly by a 12-inch-diameter cylinder (fig. 4-42). This pattern was reproduced at ATC to allow for the development of the rounds fired versus penetration correlation.

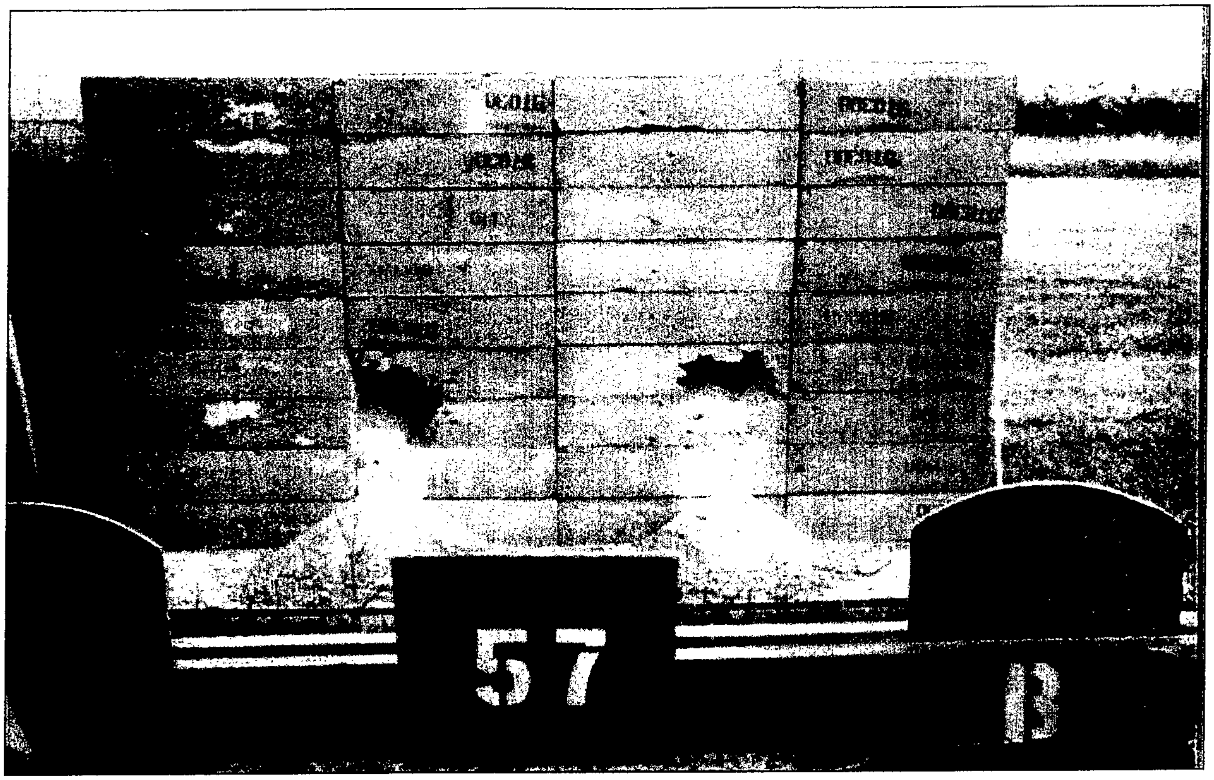


Figure 4-42. Typical cavity, Fort Knox Canby Hill Range.

Two SACON variants were tested at ATC: reformulated and recycled. Observations at Fort Knox and USMA indicated that polypropylene and steel performed similarly with respect to durability, but the debris from the steel punctured the work gloves used during the cleanup of debris. As a result of these observations, polypropylene was chosen as an additive (as opposed to steel fibers) for these variants.

Three different SACON configurations were tested at ATC. The first configuration consisted of I-shaped blocks produced from the recycled quartz-sand aggregate. The second configuration consisted of the same-shape blocks but was made using the reformulated SACON mixture. The third configuration consisted of reformulated SACON formed into large cubes with a nominal measurement of 24 inches. The walls were constructed as described in paragraph 4.2.2.7. The three SACON walls were fired upon utilizing the 5.56-mm M855 round fired from a loosely mounted squad automatic weapon (SAW) M249 machinegun. As at USMA and Fort Knox, a wall was considered failed when the penetration of the bullets reached two-thirds of the depth of the wall. The shot pattern used was 12 to 15 inches in diameter. The shot pattern was varied by the natural recoil action of a loosely mounted SAW fired in short (three- to five-round) full automatic bursts. The initial weapon sighting was moved after each 100 rounds fired to further vary the bullet impacts within the pattern. The distance from the weapon to each SACON wall was 25 meters with an incident angle-of-fire of 90°. Depth-of-penetration measurements were taken in 100-round intervals. The measurements were taken by inserting a rigid measurement device into the wall cavity and determining the maximum depth of penetration. Each measurement was taken three times to ensure repeatability. All three measurements were within 1/2 inch or they were retaken until this level of repeatability was reached.

Evaluation Procedure. Durability was analyzed by comparing the depth of penetration with the number of rounds fired. The depth-of-penetration data were reduced by averaging the three measurements made at the 100-round intervals. The data were presented in tabular form. A graphical representation of the data showing depth of penetration versus rounds fired was also made.

Since fewer rounds were expended at USMA and Fort Knox than expected, the ATC durability data were used to determine maintenance frequencies. The numbers of rounds fired into a cavity that resulted in a wall failure present a worst case for wall durability. This failure point was combined with range usage data to determine expected maintenance frequencies.

4.3.5 Training Realism (Objectives 5.1 through 5.3)

Test Procedure. The impact on training realism was characterized in terms of shooter distraction, down-range visibility, and target concealment. Shooter distraction was defined as any interruption to the shooter caused directly or indirectly by the SACON bullet trap. Reduced target visibility or masking was the obstruction of down-range targets caused by the installed SACON. Target concealment or camouflage was the degree to which identification of the target location was impacted by the installed SACON.

Evaluation Procedure. Subjective data to address training realism were collected at both Fort Knox and USMA. Immediately after the shooter finished, the officer in charge/ noncommissioned officer in charge (OIC/NCOIC) of the training unit issued a SACON Training Realism Firer Survey to each shooter using a SACON firing point. Field interviews of USMA and Fort Knox range personnel were used to enhance assessment of the objective. A histogram was used to present shooter opinions expressed on the SACON Training Realism Firer Survey (i.e., shooter distraction, down-range visibility, and target concealment).

4.3.6 Recycling Performance

4.3.6.1 Objective 6.1.

Test Procedure. The objective was to assess the ability of the recycling operation to remove M16-round steel penetrators and SACON bullet-trap steel fibers, if used. The removal of M16-round steel penetrators was deemed necessary by WES to reduce ricochet potential. To enable an assessment of removal efficiency, WES personnel collected ten samples of the crushed SACON material immediately before magnetic separation and immediately after the reconstitution of the aggregate. The samples were collected in 1-liter polyethylene plastic containers. WES used care to accumulate the 1-liter samples from ten distinct portions of the crushed material, to form a representative composite sample. The samples were mixed thoroughly to achieve homogeneity. A 4-gram portion of each sample was taken and prepared for analysis following EPA Method 3015, Microwave-Assisted Acid Digestion of Aqueous Samples and Extracts (ref 48). The prepared samples were analyzed for iron following EPA Method 6010, ICP - Atomic Emission Spectroscopy (ref 40) (table 4-3).

TABLE 4-3. RECYCLING SAMPLE MATRIX

Objective No.	Description	Target Element	Method No. Sample Preparation	Method No. Analytical	Unit Process
6.1[a]	Removal of steel penetrators/fibers	Iron	3051	6010	B Magnetic S
			3051	6010	A Blending
6.2[a]	Reduction of toxicity characteristics	Lead	3015, 1311	6010	B Magnetic S
			3015, 1311	6010	Test cylinder
6.3[b]	Containment and control of lead		3051	6010	B Breaking
					A Breaking
					B Crushing
					A Crushing
					B Magnetic S
					A Sieving
					B Blending
					A Blending
6.4[b]	Characterization of waste products		3010A	1311	PPE
			3010A	1311	Sweepings
			3010A	1311	Bags/plastic
			3010A	1311	Wash water

[a]Analysis conducted by ATC.
[b]Analysis conducted by WES.

A = After.
B = Before.

Note: WES performed all sampling.

Evaluation Procedure. A removal percentage of 95 resulted in the successful completion of the objective. The removal percentage was calculated as follows:

$$\% \text{ Removal} = \frac{(\text{Iron Concentration before Magnetic Separation} - \text{Iron Concentration after Blending}) \times 100}{\text{Iron Concentration before Magnetic Separation}}$$

4.3.6.2 Objective 6.2.

Test Procedure. The objective was to assess the ability of the recycling operation to reduce the toxicity characteristics (if present) of the SACON material. The same samples collected for analysis of steel removal efficiency (see para 4.3.6a) contained enough crushed material to evaluate the leachable lead content prior to the recycling process. A test cylinder of the final product was allowed to cure and was shipped to ATC to evaluate the leachable lead content after recycling. The samples underwent analysis following EPA Method 1311, TCLP (ref 10) to simulate the concentration of leachable lead. The TCLP-extracted samples (from EPA Method 1311) were prepared for analysis following EPA Method 3015. The prepared samples were analyzed for lead following EPA Method 6010 (table 4-3).

Evaluation Procedure. Results of less than 5 ppm of leachable lead in the leachate from the reconstituted aggregate resulted in the successful completion of Objective 6.2.

4.3.6.3 Objective 6.3.

Test Procedure. The objective was to assess the ability of the recycling operation to contain and control lead contained in the used SACON material through each step of the operation. A determination of the ability to control lead was made through analysis of the surface areas in proximity to each recycling unit process. WES sampled the floor or ground surfaces for total lead prior to and immediately after each unit operation. The after-sample was taken after the area was thoroughly cleaned by WES personnel.

Evaluation Procedure. The criteria used for the assessment were based on U.S. Housing and Urban Development (HUD) Lead-Based Paint Interim Guidelines for Hazard Identification (ref 49). Success was judged by an accumulation of less than 200 ppb of lead on the surface surrounding each unit process.

4.3.6.4 Objective 6.4.

Test Procedure. The objective was to determine waste handling requirements generated by the recycling process. All of the waste products generated during recycling operations were to be collected, weighed, and sampled by WES. WES forwarded the samples to ATC for TCLP lead analysis.

Evaluation Procedure. No criteria were required. However, the generation of a hazardous waste (TCLP lead greater than 5 mg/L) would result in more stringent handling and administrative requirements.

4.3.6.5 Objective 6.5.

Test Procedure. The objective was to assess the ability of the recycling operation to generate a usable fine aggregate that meets the Technical Specifications for SACON (ref 10). After the aggregate was blended, WES took ten 1-liter samples of the aggregate. The samples were sieved by ATC following ASTM Method C 136 (ref 50) for comparison to the Technical Specifications for SACON (ref 10).

Evaluation Procedure. Success was determined by conformance to the specification.

4.3.6.6 Objective 6.6.

Test Procedure. The objective was to compare the physical characteristics of the recycled SACON material to those of virgin SACON material. WES performed compressive strength, modulus of rupture, and density measurements. WES provided this information as well as the same data for virgin SACON material.

Evaluation Procedure. A deviation of 5 percent over any parameter was considered a failure to meet the objective.

4.3.6.7 Objectives 6.7 and 6.8.

Test Procedure. The objective was to determine the costs associated with the SACON recycling operation. WES provided a list and cost breakdown of all recurring and nonrecurring costs for comparative analysis.

Evaluation Procedure. An analysis was conducted to determine the cost to produce a pound of recycled aggregate. The cost to produce the recycled aggregate was compared with the combined cost of producing SACON from virgin aggregate and the disposal of waste SACON.

4.3.6.8 Objectives 6.9 and 6.10.

Test Procedure. The objective was to assess personnel safety and protective equipment during the performance of the SACON recycling demonstration. WES videotaped the entire recycling process. A copy of this tape was provided to ATC for review by a systems safety engineer. All recycling participants wore personnel air monitors. The monitoring results were provided to ATC for review by an industrial hygienist.

Evaluation Procedure. A safety assessment was made based on OSHA Standard 29 CFR 1910.

5. Performance Assessment

Throughout the field demonstrations, data were collected to assess each identified performance object. In the following sections, the collected data for each specific objective are presented and used to assess SACON's performance with respect to the test criteria identified in Table 4-2.

5.1 Performance Data and Assessments

5.1.1 Objective 1.1. Assess the number of rounds not retained by the SACON bullet traps.

Data. Data were collected at USMA and ATC to determine the SACON barrier containment efficiency. Table 5-1 summarizes the data that were used to calculate the number of rounds not retained by the respective barriers.

TABLE 5-1. SACON BARRIER CONTAINMENT PERFORMANCE DATA

Date Sampled	Sample Point	Debris Mass, kg	Total Lead, mg/kg	Rounds Fired (between sampling)	Rounds Not Retained
21 Apr 97	17 USMA	NR	8,416	300	NC
	19 USMA	NR	9,012	376	NC
29 Apr 97	17 USMA	NR	9.774	260	NC
	19 USMA	NR	22,380	260	NC
12 May 97	17 USMA	NR	15,660	636	NC
	19 USMA	NR	19,940	240	NC
29 May 97	17 USMA	NR	14,356	128	NC
	19 USMA	NR	12,646	128	NC
10 Oct 97	17L USMA	13.8	40,591	NR	NC
	19L USMA	10.8	64,560	NR	NC
	17R USMA	17.9	28,630	NR	NC
	19R USMA	33.0	9,362	NR	NC
15 Nov 97	17L USMA	1.9	27,568	NR	NC
	17R USMA	11.2	58,042	NR	NC
	19R USMA	17.8	28,748	NR	NC
	19L USMA	NR	14,751	NR	NC
23 Mar 98	Large block ATC	73.5	20,540	4,900	689
	Reformulated ATC	98.4	20,784	7,100	992
	Recycled ATC	84.8	19,098	7,100	865

NR = Not recorded.
NC = Not calculated.

Assessment. For purposes of the demonstration, containment was defined as the retention of bullets within the receiving SACON barrier. The percentage of rounds retained in the barrier was used as the key performance parameter. Success was to be achieved if 98 percent of the rounds which hit the barrier were retained by the barrier (ref 33). Data to support the assessment were to be derived from USMA field demonstration data. However, a lack of debris mass and/or round counts precluded the generation of a containment efficiency of the USMA 25-Meter Range barriers.

Test operations conducted at ATC were used to produce the containment efficiency assessment. Data were generated as a by-product of the accelerated durability test. The test procedure utilized for durability testing concentrated the impact of the rounds into a single cavity near the center of the wall. This is important to note because of the mechanism through which the bullets are not retained. As bullet impacts create the cavity, concrete and bullet debris accumulates within the cavity and at the base of the barrier wall. The definition of containment used excluded the accumulation at the base of the wall. From observations at USMA and Fort Knox, random shots into the barrier appear to be retained except if the impact is on a block edge. For these reasons, the test method ATC used to develop the containment efficiency data was thought to produce a worst-case containment efficiency for a well-placed barrier on a 25-Meter Range. The method used to calculate the containment efficiency is illustrated in Figure 5-1.

Given:

32.00 grain lead/antimony alloy per M855 bullet
Average antimony content in alloy = 1.75%
6.479891 x 10 $^{-5}$ kilograms per grain
Mass debris =187.0 lb x .4536 kg/lb = 84.8 kg

Calculate total lead (Pb) collected in the debris pile:

(Mass Debris, 84.8 kg) x (Debris Pb conc., 20784.3 mg/kg) x (kg/10^{6}mg) = (1.76 kg Pb lost)

Convert total lead to an estimated number of M855 bullets:

(1.76 kg Pb lost) x (M855 slug/ 31.44 grain Pb) x (grain/6.479891 x 10 $^{-5}$kg) = (863.9 M855 slugs)

Determine percentage of slugs retained by SACON wall:

$$\frac{(7100\text{, number of rounds fired}) - (864\text{, number of slugs not retained})}{(7100\text{, number of rounds fired})} \times 100 = 87.8\% \text{ captured}$$

Figure 5-1. Sample containment efficiency calculation method.

As shown by the calculation presented in Figure 5-1, the SACON wall made from recycled aggregate captured approximately 6235 of 7100 rounds fired, resulting in a containment efficiency of 87.8 percent (fig. 5-2).

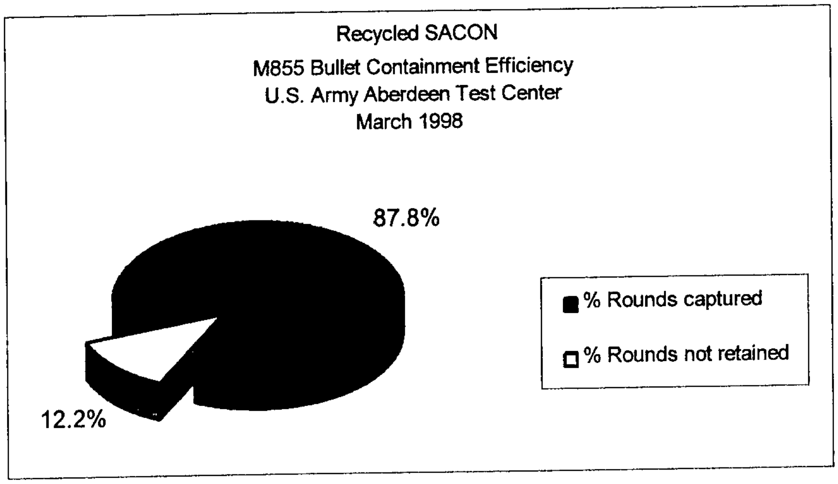


Figure 5-2. Recycled SACON containment efficiency.

The wall made from reformulated SACON captured approximately 6108 of 7100 rounds fired, resulting in a containment efficiency of 86.0 percent (fig. 5-3).

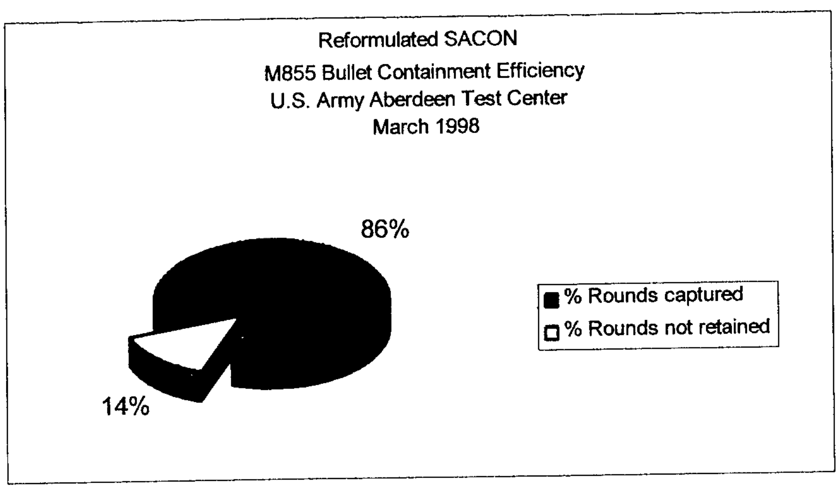


Figure 5-3. Reformulated SACON containment efficiency.

The SACON wall made from the large block configuration captured approximately 4211 of 4900 rounds fired, resulting in a containment efficiency of 85.9 percent (fig. 5-4).

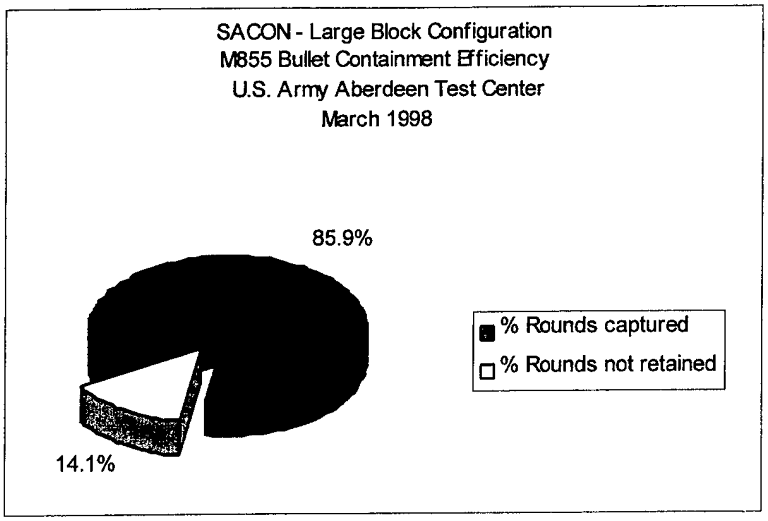


Figure 5-4. Large block SACON containment efficiency.

Using the 98-percent containment criteria specified in the *Bullet Trap Feasibility Assessment* (ref 4), the recycled or reformulated or large-block SACON variants did not provide an adequate capture rate.

Air sampling was conducted throughout durability testing. Air monitors were placed between the SACON walls. The samples were analyzed for lead and dust. The 8-hour time-weighted averages (TWAs) for lead ranged from 0.002 to 0.057 mg/m^3 and for dust from 0.05 to 5.4 mg/m^3. These results indicate that the aerial transport of lead occurred during accelerated durability testing. These results may indicate that lead dust may accumulate over time in the vicinity of the SACON barriers. The potential for aerial dispersion of lead is considered to be no greater than that associated with shooting into a berm.

Improvements to SACON containment efficiency as applied on 25-Meter Ranges could be accomplished by incorporating a debris collection pan in front of each wall. The incorporation of a debris collection device would likely raise the collection efficiency to an acceptable level for use on a 25-Meter Range.

5.1.2 Objective 1.2. Determine if debris is RCRA hazardous waste based on toxicity characteristics.

Data. Data were generated from the debris that resulted from the firing activities at USMA, Fort Knox, and ATC. The data consisted of composite SACON samples taken at the conclusion of the demonstration to characterize the SACON for disposal (table 5-2) and of samples taken from the cavities or debris piles during the demonstration (table 5-3).

TABLE 5-2. USED SACON LEAD CONCENTRATIONS

Date Sampled	Sample No.	Range Type	Sample Type	TCLP Lead, ppm
Fort Knox				
9 Apr 98	98-2701	All	Debris	0.257
	98-2702			0.366
	98-2703			0.293
	98-2704			0.374
	98-2705			0.262
	98-2706			0.328
	98-2707			0.442
	98-2708			0.295
	98-2709			0.262
	98-2710			0.230
	98-2711			0.807
	98-2712			0.679
	98-2713			0.260
	98-2714			0.368
	98-2715			0.332
	98-2716			0.277
	98-2717			0.856
	98-2718			0.301
	98-2719			0.359
	98-2720			0.285
	98-2721			0.233
	98-2722			0.253
	98-2723			0.238
	98-2724			0.240
	98-2725			0.226
	98-2726			0.392
	98-2727			0.426
	98-2728			0.410
	98-2729			0.314
	98-2730			0.239
USMA				
18 Jun 98	806336	All	Debris	ND

ND = Nondetect.

TABLE 5-3. LEAD CONCENTRATIONS IN CAVITY/DEBRIS SAMPLES

Date Sampled	Sample No.	Range Type	Firing Position No.	Sample Type	Total Lead, ppm	TCLP Lead, ppm
USMA						
21 Apr 97	9704164-01	25-Meter	17	Debris	8,416	0.884
	9704164-07		19		9,012	0.285
29 Apr 97	9705005-01		17		9,774	6.62
	9705005-07		19		22,380	13.2
12 May 97	9705113-01		17		15,660	33.7
	9705113-07		19		19,940	12.4
29 May 97	9706023-01		17		14,356	8.62
	9706023-07		19		12,646	3.94
14 Nov 97	2238		17 L/R	Cavity	15,848.54	0.20
	2241		18 L/R	Debris	5,317.76	0.02
	2240		18 L/R	Cavity	4,619.61	0.02
	2239		19 L/R		19,947.29	0.10
	2243		20 L/R	Debris	17,700.64	0.02
	2242		20 L/R	Cavity	4,171.98	1.55
10 Oct 97	20588		17L	Debris	40,591	0.22
	20589		19L		64,560	0.13
	20590		17R		28,630	0.14
	20591		19R		9,362	0.13
15 Nov 97	20665		17L		27,568	1.056
	20666		17R		58,042	0.71
	20667		19R		28,748	0.02
	20668		19L		14,751	NR
Fort Knox						
12 Dec 97	20762	25-Meter	56R	Cavity	NR	0.65
	20763		56L		NR	1.17
	20764		56L	Debris	NR	<0.10
	20765		56R		NR	1.39
	20760	CPQC	CPQC R6 wall		NR	<0.10
	20761		CPQC target No. 5 stack		NR	<0.10
ATC						
23 Mar 98	21462	25 Meter	Reformulated	Cavity	76,069	193.60
	21463		Recycled		157,000	121.00
	21464		Large block		139,717	573.00
	21465		Large block	Debris	20,540	17.80
	21466		Reformulated		20,784	63.20
	21467		Recycled		19,098	118.00

NR = Not recorded.

Assessment. A primary consideration in determining RCRA handling requirements is the waste classification of the range debris. Of particular concern is the amount of leachable lead that is present in the waste material. The amount of leachable lead present is determined by conducting EPA Test Method 1311 (Toxicity Characteristic Leaching Procedure) (CFR Part 261) (ref 11, app 2). If the leachate solution from the TCLP test contains less than 5 milligrams of lead per liter, the waste is not considered a hazardous waste and can be disposed of as a solid waste by burial in a conventional landfill after the debris has been rendered safe with respect to explosives and incendiaries (ref DOD Directive 4160.21-M-1, The Defense Demilitarization Manual, 1 Oct 91). If the leachate contains more than 5 milligrams per liter of lead, the waste is considered a hazardous waste and generates additional storage, handling, reporting, and disposal requirements. The production of a solid waste product as opposed to a hazardous waste product reduces the administrative load significantly, creates safer material handling operations, poses less of a threat to the environment, and reduces disposal costs.

The maximum theoretical lead concentration in the TCLP leachate can be estimated from the total lead concentration in the solid sample (EPA Method 1311). The maximum theoretical concentration in the leachate (mg/L) is estimated by dividing the total concentration of the lead in the solid portion (mg/kg) by 20 (EPA 902-B94-001) (ref 1). The actual TCLP lead concentrations derived from the SACON debris and cavity samples were much lower than the estimated levels. For example, a debris sample collected at USMA's 25-Meter Range position No. 20 had concentrations of 17,700 mg/L total lead and 0.02 mg/L TCLP lead. The lower TCLP levels are believed to be created through the transformation of elemental lead debris into less-soluble corrosion products through exposure to the SACON on the range.

All of the samples taken from SACON barriers that were not covered resulted in TCLP lead concentrations less than the hazardous waste criterion of 5 mg/L. Samples from SACON debris that were removed from the range shortly after shooting frequently resulted in TCLP concentrations in excess of hazardous waste limits. The USMA debris samples from the 25-Meter Range covered positions No. 17 and 19 had a higher total lead concentration but a much lower TCLP lead concentration at the end of the demonstration. This phenomenon could possibly be attributed to time and moisture content requirements for the corrosion process to occur.

5.1.3 Objective 1.3. Assess the effect of SACON bullet traps on range soil erosion.

Data. A picture of a typical erosion trough created over an undetermined length of time by bullet impacts is shown in Figure 5-5. Figure 5-6 shows a SACON-filled trench at USMA after 16 months of use on the ARF Range.

Figure 5-5. Typical erosion trough before SACON installation.

Figure 5-6. Typical erosion trough 16 months after SACON installation.

During the demonstration, the Range Supervisors were asked to answer the following: The use of SACON significantly decreases the beaten zone around the targets. The question (No. 2a) was presented on the Range Manager Survey Form. Answers were to range from -5 to represent strong disagreement through 5 to represent strong agreement. Both USMA and Fort Knox responses to the Range Inspection Survey question No. 2a have been combined, summarized, and included as Figure 5-7.

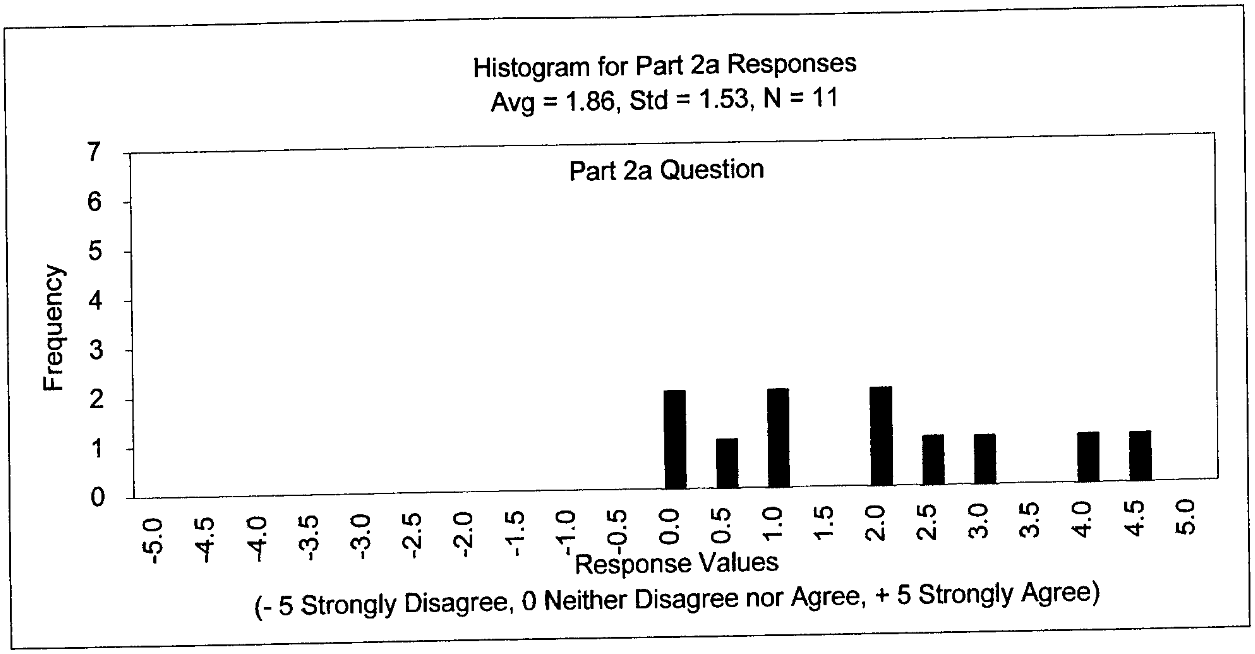


Figure 5-7. Responses to Range Inspection Survey question No. 2a.

Assessment. During the demonstration, the Range Managers at both USMA and Fort Knox had a tendency to be in agreement with question No. 2a, noting a decrease in erosion as a result of using SACON. At the conclusion of the demonstration, range personnel at Fort Knox's AFF, ARF, and CPQC Ranges were asked the following question: In your opinion, how did the use of SACON block affect soil erosion on your firing range? The CPQC Range Manager did not think SACON affected erosion greatly and mentioned a difficulty in growing grass over the covered blocks. The ARF Range Manager indicated no difference in erosion after the destruction of the SACON backstops. The AFF Range Manager indicated erosion was reduced in front of targets and noted soil replenishment was less frequent. From the limited data and ATC's range observations, it appears SACON reduced erosion on the ARF, AFF, and CPQC courses. The best performance was observed where SACON was buried in the impact paths (fig. 5-6) or buried in the berm in front of the target. Relatively rapid wear requiring frequent maintenance was observed on the majority of the above-ground backstops on the ARF, AFF, and CPQC Ranges.

5.1.4 Objective 1-4. Assess the effect of SACON bullet traps on target protection.

Data. Photographs were taken periodically throughout the demonstration period at Fort Knox and USMA. Figure 5-8 shows a typical target protection scenario in which SACON blocks were partially buried immediately in front of the target coffin. Figure 5-9 provides an example of the target protection provided by SACON near the completion of the demonstration at USMA.

Figure 5-8. Target protection, ARF - USMA.

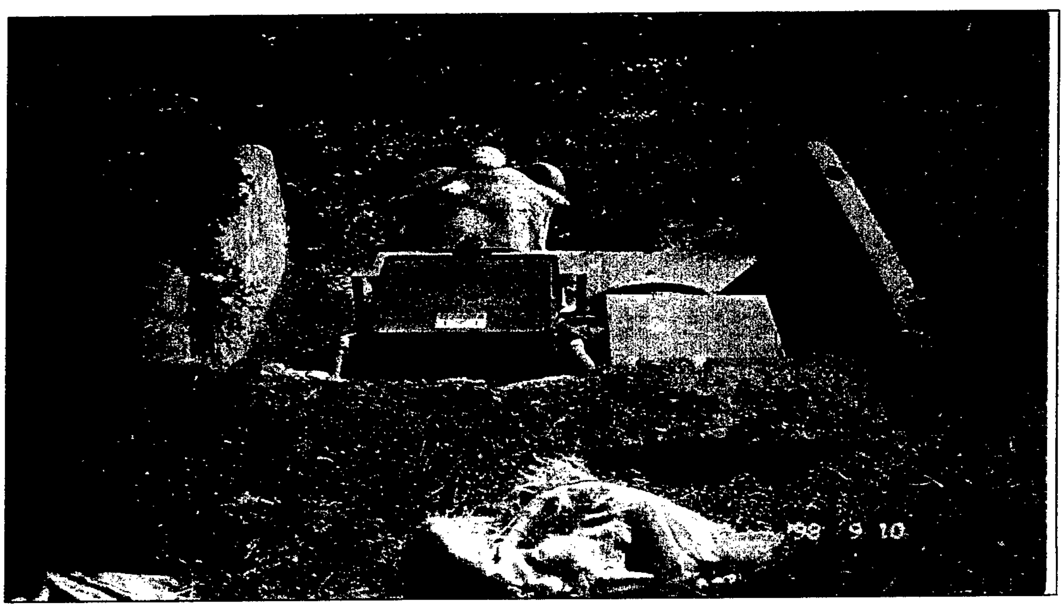


Figure 5-9. Target protection, ARF - USMA, September 1998.

The Range Supervisors were asked to answer the following question: Compared to other firing lanes, SACON significantly improves protection to the target coffin. The question (No. 2b) was presented on the Installation Range Manager Survey Form. Answers were to range from -5 to represent strong disagreement through 5 to represent strong agreement. A summary is presented as Figure 5-10.

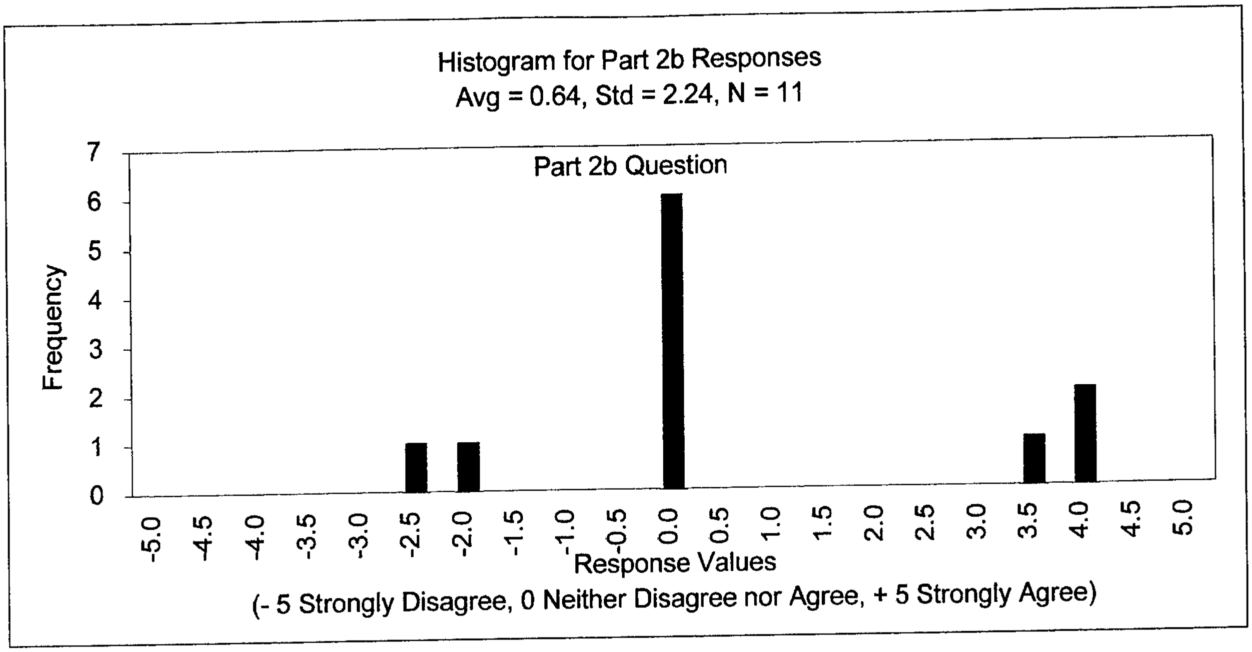


Figure 5-10. Response to Range Inspection Survey question No. 2b.

Assessment. During the demonstration, three range supervisors responded that SACON improved target protection when compared to other firing lanes. Both responses from USMA agreed that SACON increased target protection. The responses generated by Fort Knox's CPQC Range personnel were mixed: two negative, four neutral, and one positive response. Fort Knox's AFF Range Manager submitted neutral responses. With such a small sample size, it is difficult to make a definitive assessment of whether SACON provides more durable protection for the target coffin than conventional wooden barriers. The responses tended towards neutrality. With both negative responses being generated at a CPQC Range, the effectiveness of the SACON with a density of 70 lb/ft^3 is questionable.

One hundred percent of the range manager responses (11) indicated no damage to the target coffin or operating mechanism. This is supported by a disagreement with question No. 2c: Is there evidence of damage to the target coffin and/or operating mechanism?

Assuming adequate maintenance, it can be stated with confidence that SACON provided adequate target coffin protection. This conclusion was made based upon ATC observations throughout the demonstration period at both USMA and Fort Knox.

5.1.5 Objective 2.1. Determine the nonrecurring costs associated with SACON bullet traps.

Data. Nonrecurring costs associated with the use of the SACON technology are incurred during manufacturing, site evaluation, site preparation, and installation. For this portion of the analysis, a 20-lane, 25-Meter Range was assumed.

Manufacturing. The production of SACON is done with conventional materials and involves construction equipment and tools that are available to any contractor making cellular or foamed concrete. The cost of SACON can best be examined by looking at the cost of the labor and the rental or amortized cost of the required equipment. Labor rates used for the manufacturing cost estimate were taken from the Construction Engineering News Record (ref 66). SACON is an unusual concrete product in that the use of concrete-finishing equipment and skilled labor are typically not required and the formwork can be kept to a minimum. This analysis of cost assumes that 10-cubic-yard batches of SACON are made and that basic block shapes are being manufactured by casting and cutting a slab into the required block sizes.

Table 5-4 presents estimates of the costs of labor and equipment (based on rental or life-cycle cost for the major equipment) involved in manufacturing SACON blocks. An explanation of the data contained in Table 5-4 is provided after the table.

TABLE 5-4. ESTIMATE OF COSTS FOR LABOR AND EQUIPMENT FOR MANUFACTURING SACON BLOCKS (10 YD^3)

Tasks	Total Cost, $
Use of transit mixer and operating crew	550.00
Labor cost for crew involved in addition of foam and fiber One skilled laborer - 2 hr at $29.48/hr	58.96
Two unskilled laborers - 2 hr each at $22.55/hr	90.20
Equipment costs for foam generator (30-min operation)	146.33
Mixing Subtotal	**845.49**
Labor cost for crew preparing form work One skilled laborer - 4 hr at $29.48/hr	117.92
One unskilled laborer - 4 hr at $22.55/hr	90.20
Expendable materials cost for production of formwork	115.00
Formwork can be used in up to six casting operations Cost for single use is 0.167 x 335.00	55.95
Forming Subtotal	**378.87**
Labor cost for crew involved in placing and leveling SACON in forms	
One skilled laborer - 2 hr at $29.48/hr	58.96
Two unskilled laborers - 2 hr each at $22.55/hr	90.20
Materials cost for curing (curing compound)	26.00
Placing and Leveling Subtotal	**175.16**

TABLE 5-4 (CONT'D)

Tasks	Total Cost, $
Labor cost for crew cutting SACON blocks One skilled laborer - 4 hr at $29.48/hr	117.92
Two unskilled laborers - 4 hr each at $22.55/hr	180.40
Equipment cost for concrete cutting saw, $102/day	102.00
Cutting Subtotal	**400.32**
Total	**1799.84**

The SACON mixing is a three-person operation conducted by one skilled worker (foreman) and two unskilled laborers. Specialized equipment required for the operation includes a transit mixer and a foam generator pump. The cost of the transit mixer ($550) represents the cost of cleaning the truck; proportioning the cement, stabilizer, sand, and water into the transit mixer; transportation charges to move from the batch plant to the casting site; and approximately 4 hours of time for use of the truck and operator. A modern transit mixer truck can efficiently blend 10 cubic yards of SACON. As a note, approximately 3 cubic yards of SACON are required per 25-Meter Range barrier.

The entire mixing operation from setup to moving the truck to the formwork can be accomplished in approximately 2 hours. The truck operator is also an active part of the mixing crew but the labor costs are embedded in the cost of using the transit mixer. In addition to the truck operator, one skilled laborer and two unskilled laborers are necessary to add foam and fiber to the mixture. The labor cost incurred to add foam and fiber to the mixture, excluding the truck operator, is approximately $150. A foam generator is necessary to add foam to the mixture. Foam generator pumps are typically used by cellular concrete contractors and generally are not an equipment rental item. A conventional machine such as Cellular Systems model No. 680-8 sells for approximately $7000, but the life-cycle service for these units is over ten years. Assuming use of the unit by the installation to solely support the manufacture of SACON, a ten-year equipment life, and an interest rate of 3.65 percent, the annual cost for the foam generator is $848 (ref 61). Assuming after initial installation a high-use, 20-lane, 25-Meter Range requires 60 cubic yards of SACON to refurbish worn barriers annually, the cost per 10 cubic yards for the generator is $141. The foam generator is needed for only 30 minutes during the manufacturing process. The cost of using the unit on a single job, including the minor amount of fuel and lubricant utilized, amounts to approximately $5 in actual expenses.

The most economical way to form SACON is to make a slab using a frame. The slab is then cut into blocks of desired sizes. Assuming that the blocks are 6 inches thick, approximately 540 square feet of formwork is required. The labor and material producing the framing are estimated at approximately $380. The framing can be reassembled after the slab is cast and used in the manufacture of additional blocks. Generally, the framing material can be reused six times before it must be replaced.

Since SACON is a self-leveling mixture, finishing costs are less than with conventional concrete. Typically, the foamed concrete is placed in the formwork and flows to form a level surface. The top of the slab is removed with a screed and no further finishing is required. When the foamed concrete reaches an initial set, a curing compound is sprayed over the exposed surface. The slab must cure 28 days before use. The cost of leveling and treating the surface with curing compound involves an estimated $149 in labor and $26 worth of curing compound.

The SACON slab is easily cut into blocks using a concrete saw. SACON has a low density and contains no coarse aggregate; thus it cuts evenly and quickly with little blade wear. The rental cost of using a concrete saw is estimated at $102.00 per day. Cost estimates for labor are based on a three-person (one skilled, two unskilled) cutting operation that takes 4 hours. Cutting and stacking the 10 yd^3 of SACON involves an estimated $400 in labor and equipment rental.

The total labor and equipment costs for producing a 10-yd^3 batch of SACON is approximately $1800 or $180 per cubic yard.

Tables 5-5 through 5-8 provide 1997 cost data for the raw materials required to manufacture 70 lb/ft^3 (1120 kg/m^3) SACON and 90 lb/ft^3 (1440 kg/m^3) with polypropylene-fiber reinforcement and with steel-fiber reinforcement.

TABLE 5-5. MATERIAL COSTS TO MANUFACTURE 10 YD^3 OF 70 LB/FT^3 (1120 KG/M^3) POLYPROPYLENE FIBER-REINFORCED SACON

	Unit Cost	**Quantity**	**Cost, $**
Cement	0.038 $/lb	7100 lb	269.80
Sand	0.017 $/lb	7100 lb	120.70
Foam	0.115 $\$/ft^3$	139 ft^3	15.99
Stabilizer	10.25 $/lb	2.5 lb	25.63
Fiber, polypropylene	2.39 $/lb	148lb	353.72
Pigment	0.87 $/lb	213lb	185.31
Total			**971.15**

TABLE 5-6. MATERIAL COSTS TO MANUFACTURE 10 YD^3 OF 70 LB/FT^3 (1120 KG/M^3) STEEL FIBER-REINFORCED SACON

	Unit Cost	**Quantity**	**Cost, $**
Cement	0.038 $/lb	7100 lb	269.80
Sand	0.017 $/lb	7100 lb	120.70
Foam	0.115 $\$/ft^3$	139 ft^3	15.99
Stabilizer	10.25 $/lb	2.5 lb	25.63
Fiber, steel	0.41 $/lb	1930 lb	791.30
Pigment	0.87 $/lb	213 lb	185.31
Total			**1408.73**

TABLE 5-7. MATERIAL COSTS TO MANUFACTURE 10 YD^3 OF 90 LB/FT^3 (1120 KG/M^3) POLYPROPYLENE FIBER-REINFORCED SACON

	Unit Cost	Quantity	Cost, $
Cement	0.038 $/lb	9720 lb	369.36
Sand	0.017 $/lb	9720 lb	165.24
Foam	0.115 $/$ft^3$	89 ft^3	10.24
Stabilizer	10.25 $/lb	1.6 lb	16.40
Fiber, polypropylene	2.39 $/lb	148 lb	353.72
Pigment	0.87 $/lb	292 lb	254.04
Total			**1169.00**

TABLE 5-8. MATERIAL COSTS TO MANUFACTURE 10 YD^3 OF 90 LB/FT^3 (1120 KG/M^3) STEEL FIBER-REINFORCED SACON

	Unit Cost	Quantity	Cost, $
Cement	0.038 $/lb	9720 lb	369.36
Sand	0.017 $/lb	9720 lb	165.24
Foam	0.115 $/$ft^3$	89 ft^3	10.24
Stabilizer	10.25 $/lb	1.6 lb	16.40
Fiber, steel	0.41 $/lb	1930 lb	791.30
Pigment	0.87 $/lb	292 lb	254.04
Total			**1606.58**

The total estimated costs (which include labor, equipment, and material costs) to produce 10 yd^3 of the various SACON formulations are presented in Table 5-9.

TABLE 5-9. TOTAL COSTS TO PRODUCE 10 YD^3 OF SACON

SACON	Cost per 10 yd^3 produced, $
90 lb/ft^3, steel fiber	3406.42
90 lb/ft^3, polypropylene fiber	2968.84
70 lb/ft^3, steel fiber	3208.57
70 lb/ft^3, polypropylene fiber	2770.99

Transportation costs vary per locality and with required shipping distances from the point of manufacture. For estimating purposes, the SACON was assumed to have been manufactured on site. Transportation costs are thus embedded in the delivery of the raw materials.

Site preparation is considered to consist of several stages. For estimating purposes, the procedural steps and associated labor and rental costs used are those required to construct a 20-lane, 25-Meter Range at APG using ATC personnel. The first stage is environmental planning. The proposed action must undergo the National Environmental Policy Act (NEPA) review process. The cost of the review will vary greatly and is dependent upon the level of environmental documentation required. For this evaluation, an assumption was made that SACON was being placed on an existing range and that the action could be categorically excluded using Category Exclusion Number A-12 (AR 200-2). A NEPA evaluation of this type would require an Environmental Protection Specialist for approximately 4 hours at a cost of $180 (or $9 per lane, assuming a 20-lane, 25-Meter Range).

Facility costs are incurred prior to the actual installation of SACON because range drawings and operational procedures must be modified. Prior to updating the maps, the locations of the SACON barriers would need to be surveyed both for mapping and to ensure proper placement with respect to the line-of-fire. The cost of surveying the locations for 20 SACON barriers on a 20-lane, 25-Meter Range is estimated to cost $1600 (two surveyors, 20 hours each, at $40 per hour) or $80 per lane of a 20-lane, 25-Meter Range. The task of updating the range drawings is for one engineering technician to spend 16 hours updating drawings at a cost of $640 ($32 per lane). The task of updating operational procedures to include installation-specific SACON handling and disposal requirements is estimated to take the Range Supervisor 16 hours at a cost of $720 ($36 per 25-Meter Range lane).

Prior to installation, site survey work must be accomplished to ensure the location is free of utilities. At APG, the Department of Public Works (DPW) charges $300 to perform a magnetometer sweep for utility avoidance. For a 20-lane, 25-Meter Range, utility avoidance is estimated at $15 per lane.

The steps to actually prepare the site to accept SACON are simple. First, a piece of equipment such as a skid loader is rented to excavate approximately 6 inches of soil at each 25-Meter Range barrier location. The cost of the skid loader rental is approximately $200 per day. The labor requirements for the excavation are one equipment operator and two laborers to work for approximately 2 hours per barrier position. The site preparation labor is estimated at $180 per barrier location. Utilization of the skid loader is estimated at $50 per lane on a 20-lane, 25-Meter Range. Material requirements for each barrier position are for 1 cubic yard of gravel at $13.55.

The installation of the SACON blocks involves the stacking of blocks in a prescribed pattern. Four laborers can perform the stacking operation in approximately 2-1/2 hours. The labor cost for stacking the blocks is estimated at $300 per barrier position.

Table 5-10 summarizes estimates of the cost of labor and the cost of equipment (based on rental for the major equipment) involved in preparing the range for SACON installation.

TABLE 5-10. ESTIMATE OF COSTS OF LABOR AND EQUIPMENT FOR PREPARING A 20-LANE RANGE FOR SACON INSTALLATION

SACON 25-Meter Range	Total Cost, $
Site Evaluation: Conduct NEPA evaluation One environmental protection specialist, 4 hr at $45/hr	180.00
Utilities sweep	300.00
Surveying Two surveyors, 20 hr each at $40/hr	1,600.00
Administration: Modify range drawings One engineering technician, 16 hr at $40/hr	640.00
Modify operational procedures One range safety officer, 16 hr at $45/hr	720.00
Subtotal	**3,440.00**
Site Preparation: Labor costs for crew involved in grading Three laborers, 2 hr each at $30/hr	3,600.00
Equipment skid loader Five days at $200/day	1,000.00
Materials: Gravel: 20 yd^3 (delivered) at $13.55/$yd^3$	271.00
Subtotal	**4,871.00**
SACON Installation: Stacking blocks Four laborers 50 hr each at $30/hr	6,000.00
Subtotal	**6,000.00**
Total	**14,311.00**

Assessment. Nonrecurring costs associated with the use of the SACON technology are incurred during the manufacturing, site evaluation, site preparation, and installation processes. Nonrecurring cost factors have been derived for these processes based on a scenario of installing barriers on 20 lanes of a 25-Meter Range. Manufacturing costs were derived from a 10-yd^3 batch production rate of 90 lb/ft^3, polypropylene-fiber SACON. The production rate corresponds to the mixing capacity of a modern transit mixer truck. This mode of SACON manufacturing results in a production cost of approximately $297 per cubic yard. The 90-lb/ft^3 density was chosen to match the requirement for the 25-Meter Range application. Polypropylene-fiber was chosen for both economic and performance reasons. Polypropylene was cheaper to produce, was at least as durable as steel-fiber SACON, and eliminated cuts and abrasions associated with handling steel fiber SACON. The manufacturing, site evaluation, preparation, and installation result in a cost of approximately $1600 per lane to outfit a 20-lane 25-Meter Range with SACON bullet traps. Table 5-11 presents these nonrecurring cost factors.

TABLE 5-11. SACON NONRECURRING COSTS FOR ONE 25-METER FIRING LANE

Process	Cost, $
Manufacturing (3 yd^3 90 lb/ft^3 polypropylene)	891
Site evaluation	172
Site preparation	244
Installation	300
Total	**1607**

The cost factors derived based on the 10-yd^3 production are representative of material requirements for the installation of SACON on a small- to medium-sized 25-Meter Range or for the generation of replacement blocks. For larger ranges, production can be done at the 250-yd^3/day batch rate. At this scale, savings are realized through reduced equipment rental and reduced labor requirements for mixing. A mixer with 250-yd^3/day capacity can be rented for $1300 per day. Three persons are required for the 8-hour operation. At this scale, the manufacturing cost for the 90-lb/ft^3, polypropylene-fiber SACON is reduced by approximately 50 percent to approximately $152 per cubic yard.

5.1.6 Objective 2.2. Determine the recurring costs associated with SACON bullet traps.

Data. Recurring costs associated with the use of SACON technology can be broken into three categories: maintenance, waste management, and SACON manufacturing. Table 5-12 presents estimates of recurring costs associated with the operation of a 20-lane, 25-Meter Range with one firing point per lane. A high-use range scenario was assumed with an annual bullet throughput of 30,000 M855 rounds per lane. Labor costs were based upon labor rates at ATC. An explanation of the data contained in Table 5-12 is provided after the table.

TABLE 5-12. 25-METER RANGE ESTIMATED RECURRING COSTS FOR A 20-LANE, HIGH-USE 25-METER RANGE

SACON 25-Meter Range	Total Annual Cost, $ per Lane
Maintenance: Training Four range workers, 10 hr each at $30/hr	1,200.00
Preventive maintenance checks and services (PMCS) One range worker, 1/2 hr at $30/hr 50 wk/yr	750.00
Scheduled service Four range workers, 4 hr each at $30/hr 80 hr	38,400.00
Administrative	2,000.00
Subtotal	**42,350.00**

TABLE 5-12 (CONT'D)

SACON 25-Meter Range	Total Annual Cost, $ per lane
Waste Management: Environmental administration One Environmental Protection Specialist, 8 hr at $45/hr wk/yr 4/yr	1,440.00
Sampling and analytical costs	1,500
Disposal: 36,480 pounds at $0.08/lb 4/yr Materials (roll-off dumpster 4/yr)	11,673.60 1,648.00
Subtotal	**16,261.60**
Manufacture: Replacement blocks 60 yd^3 at $297/yr	17,820.00
Subtotal	**17,820.00**
Total	**76,431.60**

Range operational costs associated with the use of SACON (or any bullet trap) may be incurred through additional training requirements, PMCS, scheduled services, unscheduled services, and administrative actions. Training costs can be further divided into instruction on the operation and maintenance of the SACON bullet traps, occupational health training to ensure proper use of PPE during maintenance actions, and environmental training to ensure proper waste handling. A minimum of four persons is required to perform barrier refurbishment (stacking/restacking/ disposal), and thus these four would require training. Assuming a Range Supervisor has previously been trained, he/she should be able to provide 2 hours of SACON operational and maintenance training at a cost of $60 per person or $12 per firing lane. The occupational health training required to support the SACON technology is already necessary to support range management and no additional cost is incurred. However for estimating purposes, the cost of providing 4 hours of safety training to each of the four range workers is included. The annual cost of the safety training is estimated to be $120 per person or $24 per lane. The Installation Environmental Officer should be able to provide environmental training for range operators. The annual cost of 4 hours of environmental training is estimated to be $120 per person or $24 per firing lane. Annual environmental training would cover RCRA and stormwater management issues and would be necessary annually as a refresher for the range workers. The total cost of the annual training requirement to support the operation and maintenance of a 20-lane, 25-Meter Range is estimated to be $1200.

The PMCS requirements for SACON technology are minimal. A 30-minute weekly PMCS should suffice. For the most part, PMCS would consist of a visual inspection to determine the condition of the barrier. As a scheduled maintenance cycle approaches, depth-of-penetration measurements would be necessary to ensure the barriers have not worn past two-thirds of the wall depth. Using a cost of $30/hour for 50 inspections per year, the annual cost equates to $750.

Scheduled services for a 25-Meter Range with an annual usage rate of 30,000 rounds fired at a single target location within the lane would occur quarterly. The maintenance task would consist of removal of debris and replacement of worn blocks. The task requires four persons and an estimated 4 hours per lane or 80 hours for one 20-lane range maintenance event. Using a \$30/hour labor rate, the annual cost of scheduled service is estimated at \$38,400.

Administrative costs related to operation and maintenance include ordering supplies, planning, and maintaining PPE. Annual administrative labor is estimated at \$2000.

The maintenance cost for training and labor (excluding material costs) to maintain SACON bullet traps on a 20-lane range is estimated to be \$42,350.

Waste management tasks include administration, waste handling and storage, and waste disposal. Administratively, the Installation Environmental Officer must ensure that a proper and legal disposal mechanism exists for lead-contaminated concrete waste and that required training is accomplished to enable proper waste handling and disposal. The administrative burden on the installation environmental staff to audit operations, modify management plans, and approve waste turn-ins is estimated at one day per quarterly service, which equates to an annual cost of \$1440. Sampling and analytical costs are estimated to cost \$1500 annually. Waste disposal costs vary per locality and are dependent upon waste classification. The bulk disposal rate (1999) for lead-contaminated concrete classified as a solid waste at APG is \$0.08 per pound (ref 66). At APG, lead-contaminated concrete classified as RCRA hazardous by Code D011 (lead) costs \$0.12 per pound for bulk disposal. Materials required to support bulk disposal include a roll-off dumpster. A \$400-dollar delivery charge and a \$12-per-day rental charge are applied for its use. Transportation costs are included in these disposal quotes. The equivalent of eight blocks is estimated to be disposed of as a result of quarterly SACON maintenance on each lane of a 25-Meter Range. As a result of the nonhazardous characteristic of the waste exhibited during the demonstration, the nonhazardous bulk rate of \$0.08 per pound was chosen for estimating purposes. Eight full blocks weigh approximately 1824 pounds, which disposed of at \$0.08 per pound results in a quarterly cost of \$146. Quarterly material cost would include a \$400 delivery fee and \$12 rental fee for a roll-off dumpster. For the 20-lane range, the annual waste disposal cost is estimated to be \$13,321. The total annual waste management cost for the 20-lane outdoor range is estimated to be \$16,261.

Using a cost of \$297 per cubic yard and the need for 3 cubic yards to produce enough replacement blocks to support scheduled maintenance requirements for each firing lane, an annual manufacturing cost of \$891 is estimated per firing lane. This results in an annual SACON replacement cost of \$17,820 for the 20-lane range.

Assessment. Recurring costs associated with the use of SACON technology were broken into three categories: operation and maintenance, waste management, and SACON manufacturing. Cost factors have been derived for these recurring cost categories. The factors were calculated assuming a 20-lane, 25-Meter Range with an annual throughput of 600,000 M855 bullets. This equates to 30,000 rounds fired at a single target area on each lane. Table 5-13 presents these recurring cost factors associated with installing SACON on 1 lane of the 20-lane, 25-Meter Range.

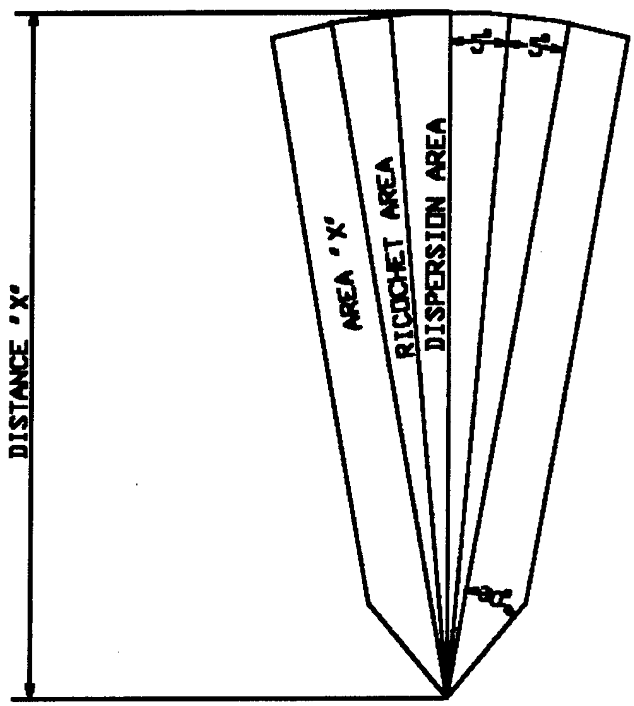
TABLE 5-13. RECURRING COSTS FOR ONE LANE OF A 25-METER FIRING RANGE

Operation	Annual Cost, $
Maintenance	2118
Waste management	813
SACON manufacturing	891
Total	**3822**

5.1.7 Objective 3.1. Determine if SACON bullet traps produce ricochets.

Data. The data generated at ATC included the impact and exit velocities, drag and trajectory results, angle results, and ricochet distance. The data are presented in Table 5-14.

Assessment. The COE ESC, Huntsville, Alabama, assessed the impact of using SACON as a bullet trap upon the respective 25-Meter, ARF, AFF, and CPQC Ranges' SDZs. Figure 5-11 illustrates the generic SDZ. The assessment was completed by plotting the termination points (fig. 5-12 through 5-15) of the ricochet projectiles upon the appropriate SDZ for small arms as published in AR 385-64 (ref 45). All ricochets resultant from ATC's testing terminated within the respective SDZ.



9mm M882, Ball —— X=1800M
.45 CAL, M1911 PISTOL/SMG ——— X=1690M
5.56 mm, M193 BALL ——— X=3100M
5.56 mm, M196 TRACER ——— X=3437
MEDIA FOR ALL CASES —— STEEL/CONCRETE

Figure 5-11. SDZ diagram.

TABLE 5-14. M855 SACON BLOCK RICOCHET TEST DATA, SACON BLOCK RICOCHET TEST

TW-1 Hard Road, J. Ayers, 5.56-mm, 9-mm, .45 caliber

Tracking Radar Operator W. Zdon, Jr., X4113

9 February to 19 March 1998

Rd No.	Block Angle, Ammo	Muzzle Velocity, m/s	Impact, m/s		Exit Velocity, m/s		Exit, deg		Maximum Estimated, m			Comments
			Velocity	Time	Uncorr	Corr	El Angle	Az Angle	Range	Deflect.	Ord	
5.56 MM												
1	2, M855	930.04	903.76	26.938	879.33	886.18	4.756	-0.066	1691	7	66	-
2	2, M855	933.36	905.90	27.137	887.10	892.14	5.855	-1.067	1514	-18	78	-
3	2, M855	930.85	904.63	27.171	911.82	915.85	5.012	-0.645	1748	-15	71	-
4	2, M855	928.63	901.83	27.258	740.85	745.30	6.621	-0.276	1300	1	72	-
5	2, M855	934.96	906.45	27.216	901.35	906.78	6.799	-0.505	1665	- 5	97	-
6	2, M855	932.48	905.79	27.173	884.69	888.73	5.473	-0.462	1706	- 1	75	-
7	2, M855	928.16	900.87	27.244	-	843.35	6.242	-0.163	1521	3	82	-
8	2, M855	932.65	906.11	27.049	832.23	836.67	6.153	0.340	1649	18	78	-
9	2, M855	925.33	898.64	27.196	798.93	803.20	6.215	0.051	1506	10	80	-
10	2, M855	944.62	918.02	26.761	918.22	922.91	5.955	0.616	1677	30	83	-
11	4, M855	930.64	902.97	27.096	656.43	664.50	8.927	0.211	1503	2	102	Extrapolated.
12	4, M855	934.86	908.49	26.851	500.08	510.51	11.783	-2.935	270	20	48	-
13	4, M855	924.09	896.54	27.318	559.92	567.10	10.372	0.013	1304	4	101	-
14	4, M855	934.01	907.22	26.982	653.33	661.12	10.075	0.004	1167	2	106	-
15	4, M855	930.84	903.42	27.018	488.29	496.21	11.649	-0.087	1142	- 1	104	-
16	4, M855	925.62	899.20	27.265	521.63	530.15	10.939	-0.235	904	1	80	-
17	4, M855	931.16	904.04	27.124	669.49	679.68	9.729	-1.346	1758	-31	123	-

TABLE 5-14 (CONT'D)

Rd No.	Block Angle, Ammo	Muzzle Velocity, m/s	Impact, m/s		Exit Velocity, m/s		Exit, deg		Maximum Estimated, m			Comments
			Velocity	Time	Uncorr	Corr	El Angle	Az Angle	Range	Deflect.	Ord	
18	4, M855	927.29	901.09	27.129	359.43	367.08	11.470	1.529	1011	32	73	-
19	4, M855	925.21	898.34	27.090	593.97	603.62	11.566	0.937	1668	33	134	-
20	4, M855	932.59	905.34	26.941	563.09	573.57	12.935	2.009	187	- 9	27	-
21	6, M855	928.29	900.77	27.330	329.60	365.86	26.438	2.985	118	20	33	-
22	6, M855	934.87	907.18	27.157	450.86	492.58	23.576	1.615	603	71	146	Extrapolated.
23	6, M855	936.48	909.27	27.128	290.58	300.26	23.708	-2.454	588	4	129	-
24	6, M855	937.89	909.77	27.078	395.55	418.90	20.164	-1.422	588	6	114	-
25	6, M855	937.57	910.21	27.045	405.55	436.61	23.979	3.364	601	94	149	-
26	6, M855	929.51	903.19	27.292	452.30	473.77	19.266	0.171	607	55	119	-
27	6, M855	934.88	908.76	27.042	308.50	312.30	18.919	-2.147	596	- 15	93	-
28	6, M855	925.88	900.13	27.368	241.06	267.09	40.829	0.754	169	28	42	-
29	6, M855	932.09	905.84	27.234	304.20	325.25	20.115	-1.622	322	21	49	-
30	6, M855	937.19	910.63	27.004	451.12	475.80	16.964	-3.164	398	3	73	-
31	8, M855	932.67	905.72	27.212	342.77	376.54	25.471	3.711	534	79	138	-
32	8, M855	937.83	911.56	27.055	300.05	332.15	25.375	-0.112	424	30	113	-
33	8, M855	932.71	906.07	27.191	374.40	405.38	23.946	1.405	579	70	141	-
34	8, M855	938.94	912.34	27.035	374.49	408.07	24.674	2.609	584	88	150	-
35	8, M855	927.57	899.71	27.434	500.85	539.32	23.272	2.917	625	91	155	-
36	8, M855	932.66	905.73	27.180	299.40	342.70	27.636	6.306	517	123	154	-
37	8, M855	937.49	910.36	27.023	362.55	391.58	24.285	0.683	569	59	140	-
38	8, M855	937.56	911.15	27.035	374.13	403.96	23.995	1.751	591	82	147	-
39	8, M855	925.70	898.92	27.369	389.85	428.37	26.608	6.849	566	139	165	-
40	8, M855	937.16	909.37	27.021	235.95	239.29	19.607	1.946	491	- 1	73	-
41	10, M855	936.66	910.46	27.097	165.67	203.80	35.791	8.554	252	92	92	-
42	10, M855	936.38	909.86	27.130	310.54	349.62	29.194	1.288	533	79	160	-

TABLE 5-14 (CONT'D)

Rd No.	Block Angle, Ammo	Muzzle Velocity, m/s	Impact, m/s		Exit Velocity, m/s		Exit, deg		Maximum Estimated, m			Comments
			Velocity	Time	Uncorr	Corr	El Angle	Az Angle	Range	Deflect	Ord	
114	14, M855	939.98	913.70	27.027	233.94	289.82	44.941	12.870	36	6	30	Not to the ground, lost track.
115	14, M855	942.44	915.83	26.940	36.57	70.57	54.093	1.651	45	10	21	Not to the ground, 20 m.
116	14, M855	939.12	913.10	27.059	173.11	233.55	40.356	16.162	53	14	48	Not to the ground, 48 m, 15 ms.
117	14, M855	928.00	901.95	27.397	134.65	217.44	50.801	- 4.778	31	9	44	Not to the ground, 43 m, 1 ms.
118	14, M855	931.41	905.30	27.257	-	-	-	-	-	-	-	No ricochet.
119	14, M855	934.45	906.76	27.188	172.48	227.07	38.974	-10.843	154	15	69	-
120	14, M855	930.30	904.18	27.288	143.00	179.45	42.320	- 9.377	52	-26	41	Not to the ground, 41 m, 24 ms.
121	14, M855	945.70	919.42	26.812	117.31	185.77	60.661	- 3.606	59	47	35	Not to the ground, 26 m, 13 ms.
122	16, M855	943.92	918.63	26.909		248.39	43.352	0.501	50	2	28	Not to the ground, 27 m, 14 ms.
123	16, M855	942.37	917.86	26.927	298.41	446.80	41.778	-46.414	-		-	Lost track.
124	16, M855	947.71	922.44	26.813	65.51	105.48	50.314	-17.038	55	17	47	Not to the ground, 46 m, 1 ms.
125	16, M855	940.08	914.95	27.040	130.32	150.70	29.688	15.621	136	30	58	Not to the ground, 50 m, 13 ms.
126	16, M855	934.86	909.33	27.153	102.44	249.46	48.023	-17.184	43	-53	54	Not to the ground, 54 m, 14 ms.
5.56 MM												
43	2, M193	990.71	956.74	25.332	914.26	921.06	5.267	0.855	917	36	47	-
44	2, M193	978.17	945.27	25.948	737.00	742.00	9.733	1.181	199	7	15	-
45	2, M193	992.06	957.97	25.612	813.82	816.50	9.722	- 2.061	432	49	31	-

TABLE 5-14 (CONT'D)

Rd No.	Block Angle, Ammo	Muzzle Velocity, m/s	Impact, m/s		Exit Velocity, m/s		Exit, deg		Maximum Estimated, m			Comments
			Velocity	Time	Uncorr	Corr	El Angle	Az Angle	Range	Deflect.	Ord	
46	2, M193	981.25	948.21	25.672	674.07	679.39	4.891	-1.233	244	- 1	12	-
47	2, M193	980.51	946.24	25.846	912.03	923.44	2.762	-1.099	362	1	20	Extrapolated.
48	2, M193	983.06	948.52	25.563	914.43	928.51	0.680	-4.236	217	-21	9	Extrapolated.
49	2, M193	979.31	945.63	25.835	535.19	538.58	5.745	-0.991	317	-1	16	-
50	2, M193	980.41	948.25	25.821	929.93	934.49	3.717	-0.258	1375	- 1	38	Extrapolated.
51	2, M193	985.43	950.41	25.820	933.28	936.86	3.586	-0.219	1352	2	32	-
52	2, M193	983.72	948.87	25.770	929.90	934.56	3.940	-0.015	1334	2	45	-
53	2, M193	962.10	928.83	26.340	864.24	866.74	3.193	-0.507	1245	- 6	27	Extrapolated.
54	4, M193	973.82	939.94	26.210	866.57	879.18	7.873	0.130	159	-17	9	-
55	4, M193	966.90	932.22	26.351	333.35	345.82	16.168	3.813	85	6	12	-
56	4, M193	965.92	931.08	26.401	870.16	890.69	13.376	4.587	146	8	15	-
57	4, M193	971.76	935.38	26.205	837.06	858.20	15.378	6.824	149	31	22	-
58	4, M193	962.79	928.27	26.401	317.75	321.76	10.136	3.347	87	- 0	11	-
59	4, M193	974.40	940.52	26.167	407.11	416.16	11.486	0.510	84	0	11	-
60	4, M193	974.69	941.23	26.081	749.38	758.74	7.834	-1.329	702	- 3	48	-
61	4, M193	975.19	939.53	26.090	266.90	284.70	18.648	-5.967	105	- 4	19	-
62	4, M193	976.35	941.28	26.054	705.93	715.30	10.687	-4.710	198	-34	20	-
63	4, M193	977.24	944.00	26.023	518.98	528.42	10.245	2.241	107	5	12	-
64	6, M193	972.45	937.67	26.213	799.47	817.37	11.149	1.292	104	14	11	-
65	6, M193	981.72	949.40	25.864	776.03	821.67	14.574	2.826	-	-	-	Lost track.
66	6, M193	998.55	936.47	25.513	430.63	448.71	17.471	-0.208	166	9	30	-
67	6, M193	972.10	937.54	26.069	500.93	523.43	15.213	-3.059	146	-10	18	-
68	6, M193	964.64	930.94	26.364	267.46	280.28	14.749	-8.474	79	- 0	11	-
69	6, M193	966.18	932.01	26.322	244.48	256.30	17.297	-1.028	234	41	33	Not to the ground, 15 m, 24 ms.

TABLE 5-14 (CONT'D)

Rd No.	Block Angle, Ammo	Muzzle Velocity, m/s	Impact, m/s		Exit Velocity, m/s		Exit, deg		Maximum Estimated, m			Comments
			Velocity	Time	Uncorr	Corr	El Angle	Az Angle	Range	Deflect.	Ord	
70	6, M193	972.32	938.97	26.147	389.95	404.36	14.356	-2.727	83	- 5	10	-
71	6, M193	977.77	944.46	26.032	404.91	419.51	13.279	-2.904	197	4	27	-
72	6, M193	992.52	957.86	25.560	572.55	594.10	16.897	-2.006	152	4	23	-
73	6, M193	985.52	950.93	25.737	400.70	426.77	18.266	-1.000	73	- 2	12	Not to the ground, 4 m, 9 ms.
74	8, M193	985.98	953.88	25.811	371.25	389.48	17.948	-5.375	158	- 1	34	-
75	8, M193	977.92	940.93	26.016	232.28	260.95	26.521	0.077	95	9	27	-
76	8, M193	951.35	918.80	26.738	318.68	342.61	22.203	2.887	131	20	36	-
77	8, M193	971.84	939.23	26.249	376.33	391.37	16.062	0.202	153	31	52	Not to the ground, 6 m, 23 ms.
78	8, M193	973.44	941.59	26.136	326.55	353.79	20.231	5.413	-	-	-	Lost track.
79	8, M193	975.00	945.40	26.070	298.16	309.61	19.254	5.981	194	8	32	-
80	8, M193	987.26	957.38	25.782	421.37	459.28	24.614	-3.355	155	10	43	Not to the ground, 13 m, 6 ms.
81	8, M193	993.87	960.17	25.590	254.54	317.27	33.117	-4.792	60	-33	24	Not to the ground, 11 m, 12 ms.
82	8, M193	982.97	951.37	25.849	248.93	281.43	18.091	2.940	70	4	17	Not to the ground, 5 m, 2 ms.
83	8, M193	992.12	959.49	25.636	256.12	289.55	27.984	-1.778	73	10	20	Not to the ground, 16 m, 10 ms.
84	10, M193	985.74	951.90	25.863	375.58	472.68	40.965	6.540	38	4	21	Not to the ground, 18 m, 7 ms.
85	10, M193	989.00	955.30	25.753	378.86	577.26	49.608	-0.651	42	7	25	Not to the ground, 17 m, 14 ms.
86	10, M193	989.11	955.34	25.738	427.18	444.61	10.437	-3.155	80	- 2	19	Not to the ground, 13 m, 23 ms.

TABLE 5-14 (CONT'D)

Rd No.	Block Angle, Ammo	Muzzle Velocity, m/s	Impact, m/s		Exit Velocity, m/s		Exit, deg		Maximum Estimated, m			Comments
			Velocity	Time	Uncorr	Corr	El Angle	Az Angle	Range	Deflect.	Ord	
87	10, M193	985.85	951.51	25.861	192.32	221.91	31.699	3.453	122	-13	22	-
88	10, M193	976.59	942.66	26.117	379.34	33.81	- 0.281	-	-	-	-	Lost track.
89	10, M193	988.99	952.83	25.821	343.34	399.53	35.310	- 1.543	-	-	-	Lost track.
90	10, M193	995.27	962.33	25.615	414.24	534.17	38.383	8.795	40	- 0	18	Not to the ground, 14 m, 9 ms.
91	10, M193	996.87	962.60	25.511	390.97	454.09	25.466	9.190	46	- 3	11	Not to the ground, 10 m, 9 ms.
92	10, M193	975.77	943.48	26.120	124.67	163.30	46.915	- 3.923	42	0	11	-
93	10, M193	992.76	959.69	25.681	203.79	218.25	14.918	7.500	64	8	8	Not to the ground, 6 m, 16 ms.
94	12, M193	968.51	936.96	26.262	341.91	375.69	25.974	3.984	84	69	31	Extrapolated.
95	12, M193	983.41	966.09	25.667	142.24	162.49	31.162	- 3.793	103	6	31	Extrapolated.
96	12, M193	971.92	937.93	26.204	173.02	223.19	37.765	- 6.339	97	5	28	Extrapolated.
97	12, M193	972.22	938.46	26.199	133.03	210.88	50.013	2.200	59	36	28	Extrapolated.
98	12, M193	985.22	957.76	25.768	154.02	207.77	43.488	12.622	47	10	15	-
99	12, M193	985.40	953.34	25.832	-	-	-	-	-	-	-	No ricochet.
9 MM												
128	2, M882	387.29	361.28	65.439	332.07	334.42	6.289	0.682	922	23	36	-
129	2, M882	391.00	361.11	66.673	344.30	345.86	2.951	- 0.021	578	3	9	-
130	2, M882	381.09	353.33	66.377	328.77	331.55	4.146	- 0.279	732	5	18	-
131	2, M882	389.27	360.05	65.656	322.61	329.17	6.766	1.562	984	57	40	-
132	2, M882	386.35	358.62	65.013	331.81	336.40	5.361	- 0.361	851	10	28	-
133	2, M882	389.21	360.36	65.447	324.66	329.89	6.748	1.050	977	42	40	-
134	2, M882	392.17	362.95	64.442	336.80	338.69	4.293	- 0.102	784	10	21	-
135	2, M882	391.62	361.82	64.549	320.59	324.37	6.799	0.800	944	35	39	-
136	2, M882	377.34	349.32	68.398	334.19	335.52	3.217	- 0.377	593	- 2	10	-

TABLE 5-14 (CONT'D)

Rd No.	Block Angle, Ammo	Muzzle Velocity, m/s	Impact, m/s		Exit Velocity, m/s		Exit, deg		Maximum Estimated, m			Comments
			Velocity	Time	Uncorr	Corr	El Angle	Az Angle	Range	Deflect.	Ord	
137	2, M882	390.08	360.08	65.692	327.53	328.67	3.511	- 0.131	592	3	10	-
138	6, M882	387.50	358.30	66.034	316.38	321.60	6.104	- 0.336	831	12	30	-
139	6, M882	398.39	367.21	64.445	276.27	284.60	13.340	1.513	1092	80	98	-
140	6, M882	396.05	365.25	65.158	242.75	248.82	13.944	4.648	963	126	88	-
141	6, M882	393.65	363.23	65.706	270.36	276.39	12.576	2.133	977	87	79	-
142	6, M882	380.08	352.40	67.883	275.61	287.61	16.030	3.923	912	127	83	-
143	6, M882	394.82	364.52	65.096	281.21	292.33	14.810	2.664	882	103	78	-
144	6, M882	386.44	356.96	66.941	203.79	217.03	17.100	3.843	-	-	-	Lost track.
145	6, M882	396.96	366.29	64.936	272.28	283.46	15.992	4.580	794	119	84	-
146	6, M882	388.90	358.40	66.925	278.65	286.18	12.324	3.518	816	97	65	-
147	6, M882	386.66	357.13	66.851	276.53	283.22	11.368	3.501	756	76	54	-
148	10, M882	394.09	363.99	65.616	29.68	40.22	39.345	5.618	84	25	23	-
149	10, M882	389.00	359.51	66.268	15.26	30.21	57.815	11.466	-	-	-	Lost track.
150	10, M882	384.36	356.24	67.036	33.33	43.26	37.937	1.278	97	-4	22	-
151	10, M882	392.31	362.68	65.786	75.99	87.91	28.733	6.162	173	22	28	-
152	10, M882	396.17	365.14	65.437	25.65	48.35	46.109	43.584	68	78	28	-
153	10, M882	390.45	361.25	65.845	33.64	47.20	42.910	3.315	113	13	27	-
154	10, M882	393.57	363.63	65.349	106.74	120.23	25.593	9.808	216	26	35	-
155	10, M882	387.53	358.65	66.314	152.01	134.80	22.536	6.291	255	4	35	-
156	10, M882	403.50	371.70	63.957	74.33	84.22	28.943	7.775	163	25	28	-
157	10, M882	402.69	371.05	64.049	163.35	174.38	21.757	5.048	258	- 2	32	-
158	14, M882	382.53	354.44	67.320	127.01	163.97	36.335	-14.655	52	2	19	Extrapolated.
159	14, M882	382.89	354.55	67.121	-	-	-	-	-	-	-	No ricochet.
160	14, M882	401.24	369.55	64.317	-	-	-	-	-	-	-	No ricochet.
161	14, M882	392.00	362.42	65.763	12.07	22.72	60.625	23.087	41	23	20	-
162	14, M882	395.15	365.12	65.159	-	-	-	-	-	-	-	No ricochet.

TABLE 5-14 (CONT'D)

Rd No.	Block Angle, Ammo	Muzzle Velocity, m/s	Impact, m/s		Exit Velocity, m/s		Exit, deg		Maximum Estimated, m			Comments
			Velocity	Time	Uncorr	Corr	El Angle	Az Angle	Range	Deflect.	Ord	
163	14, M882	409.06	376.62	62.889	-	-	-	-	-	-	-	No ricochet.
164	14, M882	389.80	359.70	66.271	-	-	-	-	-	-	-	No ricochet.
165	14, M882	386.76	357.38	67.004	-	-	-	-	-	-	-	No ricochet.
166	14, M882	385.93	357.15	66.813	-	-	-	-	-	-	-	No ricochet.
167	14, M882	402.28	370.80	64.808	-	-	-	-	-	-	-	No ricochet.
.45 Caliber												
168	14, M1911	296.00	262.93	95.049	-	-	-	-	-	-	-	No ricochet.
169	14, M1911	265.88	259.87	95.176	-	-	-	-	-	-	-	No ricochet.
170	14, M1911	267.99	262.09	94.136	-	-	-	-	-	-	-	No ricochet.
171	14, M1911	273.97	268.23	92.072	-	-	-	-	-	-	-	No ricochet.
172	14, M1911	277.28	271.61	91.087	-	-	-	-	-	-	-	No ricochet.
173	14, M1911	269.72	263.79	93.551	-	-	-	-	-	-	-	No ricochet.
174	14, M1911	269.08	263.10	93.951	-	-	-	-	-	-	-	No ricochet.
175	14, M1911	265.86	259.90	94.815	-	-	-	-	-	-	-	No ricochet.
176	14, M1911	276.33	270.35	91.516	-	-	-	-	-	-	-	No ricochet.
177	14, M1911	269.61	263.89	93.688	-	-	-	-	-	-	-	No ricochet.
178	10, M1911	271.61	265.61	92.692	49.75	61.30	35.685	16.759	172	67	41	-
179	10, M1911	274.40	268.13	92.230	65.50	76.43	30.850	12.855	195	80	40	-
180	10, M1911	266.53	260.84	94.337	86.95	99.99	28.385	7.328	-	-	-	Lost track.
181	10, M1911	273.72	267.87	92.332	58.81	75.28	36.870	11.260	-	-	-	Lost track.
182	10, M1911	261.49	255.91	96.500	95.78	105.52	25.748	9.920	501	116	79	-
183	10, M1911	273.35	267.44	92.196	96.34	106.46	24.097	8.357	-	-	-	Lost track.
184	10, M1911	266.44	260.66	110.606	104.55	171.71	7.377	- 1.530	330	8	26	-
185	10, M1911	263.01	257.65	95.501	119.82	128.44	20.315	7.035	446	81	55	-
186	10, M1911	270.75	264.94	92.804	161.19	170.62	24.375	6.138	853	161	126	-
187	10, M1911	269.44	263.61	93.271	129.18	143.11	24.963	7.270	693	145	107	-

TABLE 5-14 (CONT'D)

Rd No.	Block Angle, Ammo	Muzzle Velocity, m/s	Impact, m/s		Exit Velocity, m/s		Exit, deg		Maximum Estimated, m			Comments
			Velocity	Time	Uncorr	Corr	El Angle	Az Angle	Range	Deflect.	Ord	
188	6, M1911	267.10	261.65	93.537	174.04	181.18	17.595	3.377	726	81	77	-
189	6, M1911	269.07	263.28	92.244	196.32	203.33	16.259	3.576	804	91	79	-
190	6, M1911	259.67	254.19	95.589	219.90	224.58	12.047	0.629	871	42	62	-
191	6, M1911	266.82	261.18	93.694	176.24	185.62	18.191	4.759	897	123	89	-
192	6, M1911	259.67	253.95	96.446	194.14	200.05	12.860	1.864	733	49	56	-
193	6, M1911	274.85	269.06	91.037	216.11	223.36	14.645	3.127	1008	86	89	-
194	6, M1911	259.15	253.54	96.062	217.92	222.23	10.751	0.034	879	23	55	-
195	6, M1911	276.52	270.36	90.864	186.02	195.15	17.244	5.119	792	111	81	-
196	6, M1911	264.24	258.76	94.761	178.96	188.71	18.326	2.583	752	71	88	-
197	6, M1911	272.77	267.27	92.049	160.62	173.28	22.622	5.522	709	122	101	-
198	2, M1911	273.24	267.51	89.830	227.74	233.39	10.974	0.831	925	41	59	-
199	2, M1911	273.02	267.26	89.876	196.00	203.41	12.809	3.602	752	75	56	-
200	2, M1911	264.68	259.24	92.366	221.02	225.92	9.387	1.278	789	34	41	-
201	2, M1911	264.00	258.62	92.431	235.11	239.13	7.980	0.878	822	25	36	-
202	2, M1911	270.68	265.15	90.240	239.82	243.93	7.700	0.505	821	19	36	-
203	2, M1911	272.47	266.80	89.491	217.87	222.36	9.746	1.475	719	36	38	-
204	2, M1911	271.26	265.52	90.868	248.44	251.36	6.427	-0.005	767	9	27	-
205	2, M1911	270.05	264.25	92.185	235.06	238.94	7.533	0.037	733	11	30	-
206	2, M1911	273.90	267.96	90.905	244.79	247.62	6.203	-0.123	741	7	25	-
207	2, M1911	270.75	264.96	92.387	250.70	253.44	5.631	-0.422	700	2	20	-

Ammo = Ammunition.
Az = Azimuth.
Corr = Corrected.
Deflect. = Deflection.
El = Elevation.
Ord = Ordinate.
Uncorr = Uncorrected.

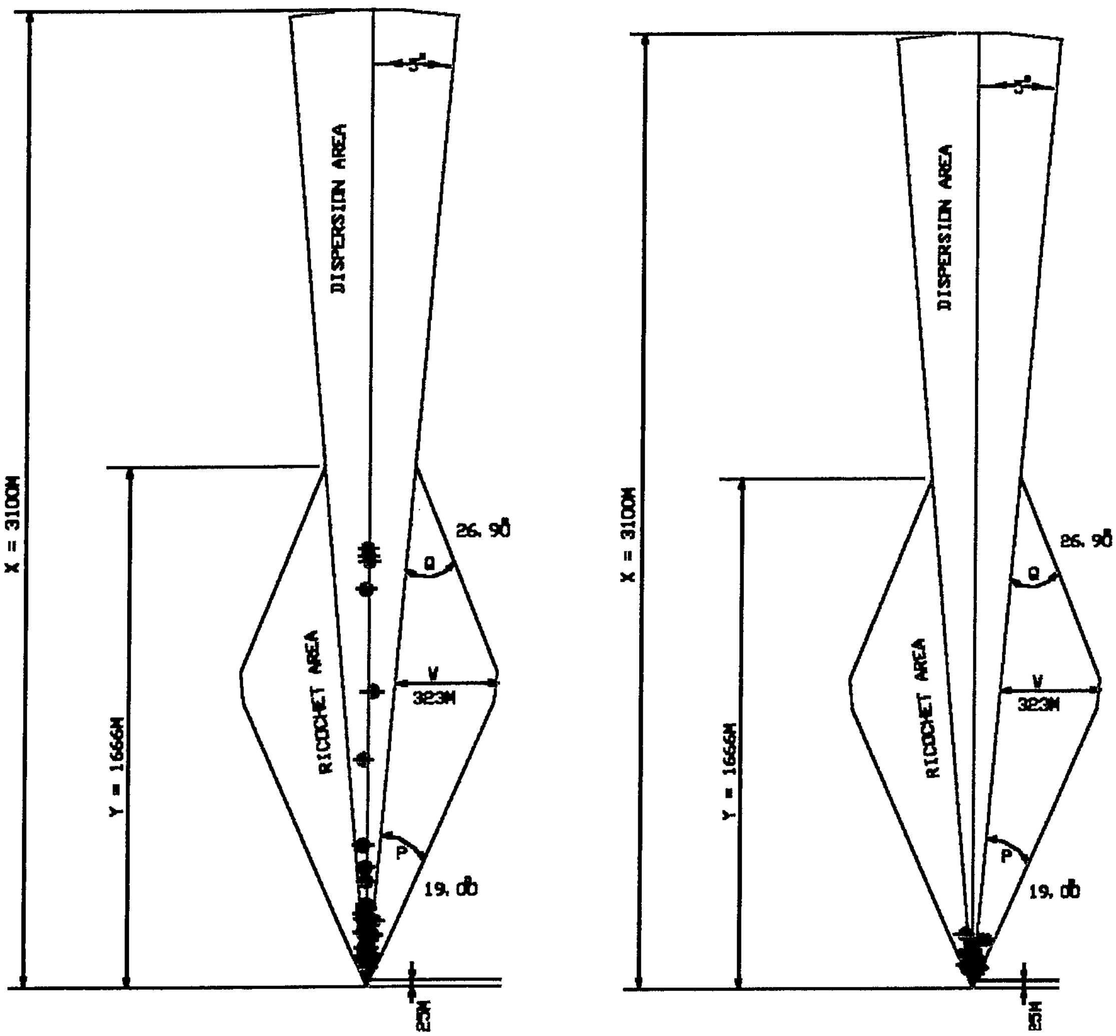


Figure 5-12. M193 SDZ, Block Angles (degrees) 2, 4, 6, 8, 10, 12, 14, 16.

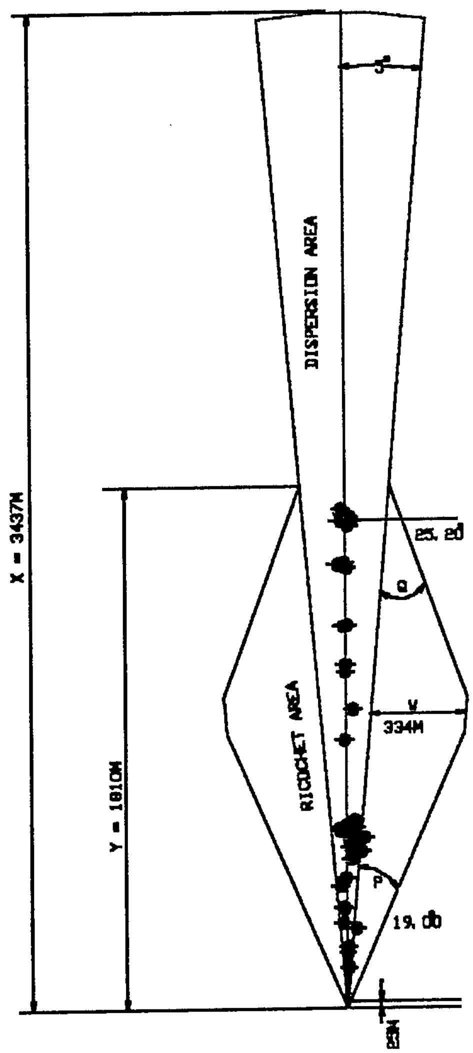


Figure 5-13. M855 SDZ, Block Angles (degrees) 2, 4, 6, 8, 10.

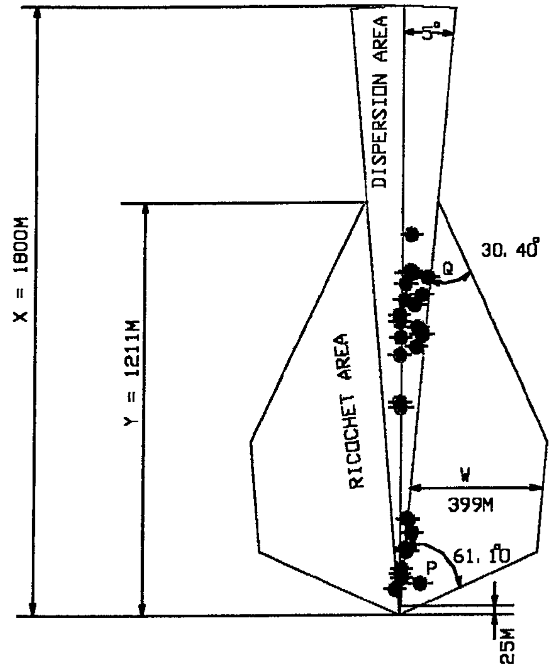


Figure 5-14. M882 SDZ.
Block Angles (degrees) 2, 6, 10, 14.

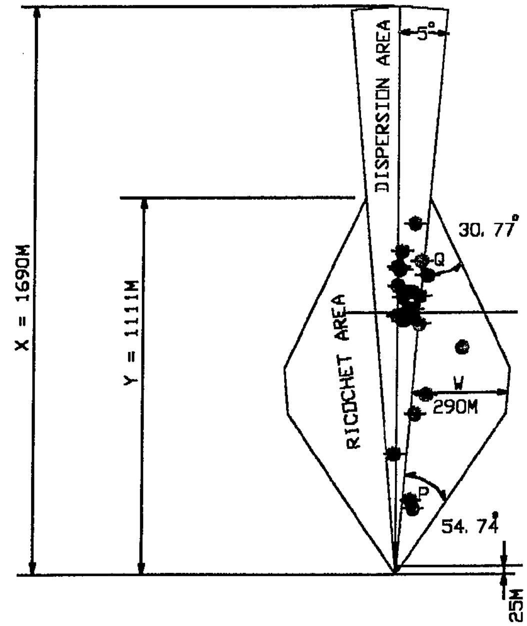


Figure 5-15. M1911 SDZ.
Block Angles (degrees) 2, 6, 10, 14.

The COE ESC determined that the application of SACON on the 25-Meter, ARF, AFF, and CPQC Ranges would not require adjustment of the SDZ. This assessment was based upon dry weather testing by ATC and upon previous testing under frozen conditions conducted by WES and COE ESC. The results of the ricochet assessment were sent to the U.S. Army Training and Doctrine Command (TRADOC), Range Safety Program Manager, by COE ESC for certification to use SACON blocks on the 25-Meter, ARF, AFF, and CPQC Ranges.

5.1.8 Objective 3.2. Assess safety during installation and maintenance of the SACON bullet traps.

Data. The procedures employed during barrier refurbishment were evaluated from a personnel safety perspective. The assessment focused upon inhalation exposures as well as lifting and handling requirements. Table 5-15 provides mass data for the various SACON block shapes. Table 5-16 presents the results of industrial hygiene monitoring during SACON barrier removal efforts.

TABLE 5-15. MASS OF VARIOUS SACON OBJECTS

Object Type	Volume, ft^3	Density, lb/ft^3	Mass, lb	Mass, kg
Full I-block	2.53	90	227.7	103.4
Half I-block	1.27	90	113.9	51.7
8-in. diameter, 72-in. long log	2.09	90	188.5	85.5
12-in. diameter, 30-in. long log	1.96	90	176.4	80.2
30-in. long, 10-in. wide, 6.5-in. high block	1.13	90	101.6	46.1
8-in. diameter, 72-in. long log	2.09	70	146.3	66.4
30-in. long, 10-in. wide, 6.5-in. high block	1.13	70	79.1	35.9

TABLE 5-16. INDUSTRIAL HYGIENE RESULTS, BARRIER REMOVAL ACTIONS

Date, 1997	Weather	Operation Description	Lead, mg/m^3		Exposure Category	WES PPE Required	WES ID No.
			Exposure	Limit			
3 Dec	No rain, sun	Disassemble barriers	0.510	0.05	3e	Mandatory	PZ970142
	No rain, sun		< .014	.05	1e		PZ970141
4 Dec	Misty rain		.016	.05	1e		PZ970144
	Misty rain		.043	.05	2e		PZ970146
	Misty rain		< .017	.05	1e		PZ970145

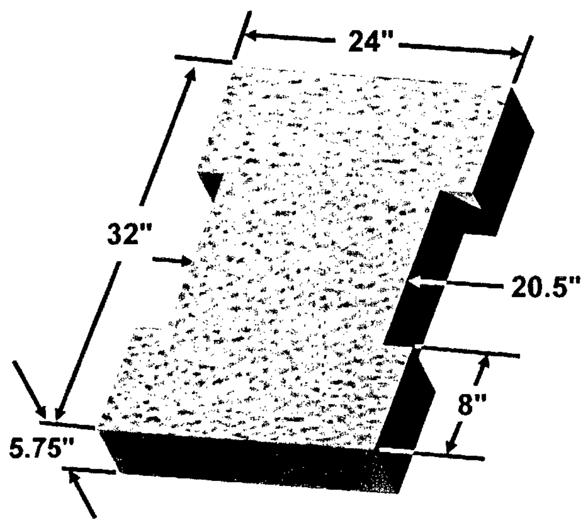
Assessment. Bullets impacting SACON create debris consisting of SACON chunks, dust, bullet slugs, and bullet fragments. The dust contains both crushed SACON and lead particles. At USMA Range 3, personnel performing the barrier removal action were monitored for lead exposure. It should be noted that the barriers removed at the conclusion of the demonstration had not reached failure and thus would have collected more bullet fragments prior to a barrier refurbishment action being necessitated.

The USMA Range 3 removal action occurred over two days and produced data that illustrated a dependence of airborne lead concentrations upon weather conditions. On 3 December 1997, the weather at USMA was clear and sunny with no rain. The results showed lead exposures of less than 0.014 and 0.51 mg/m^3. The 0.51-mg/m^3 result is significant because it indicates the individual without PPE would have been exposed to lead levels above the 0.05-mg/m^3 permissible limit (ref 47). On 4 December 1997, USMA received a misty rain. The maximum lead exposure level recorded was about ten times less than the day before but still close to the permissible limit.

From visual observations, the amount of dust produced by the barrier removal action was a function of the weather conditions. Incorporating the wetting of the debris into operational procedures would reduce the inhalation hazard. However, the hazard reduction would not eliminate the need for PPE to mitigate lead inhalation hazards.

Human engineering criteria for the design and development of military systems, equipment, and facilities are standardized by MIL-STD-1472E (ref 46). The purpose of this Military Standard is to present human engineering design criteria, principles, and practices that are to be applied in the design of systems, equipment, and facilities. The analysis of the lifting action required to install (stack) and to refurbish (unstack/restack) SACON barriers as configured for use on the 25-Meter Range was derived from design weight limitations presented in MIL-STD-1472E.

The blocks used to form the 25-Meter Range barrier had been cast into an I-shape (fig. 5-16). The SACON blocks were manufactured to achieve a density of 90 lb/ft^3 and weighed an average of 228 pounds (103 kg).



SACON "I" Block

Figure 5-16. I-shaped SACON block.

The design weight limits are the maximum design weights allowable for one person lifting with both hands, providing that the object is of convenient configuration. These values can be doubled if the object is conformed in a manner in which a two-man lift can be safely conducted with an equal distribution of the load. Where three or more persons are lifting simultaneously, not more than 75 percent of the one-person value may be added for each additional lifter, provided that the object is sufficiently large that the lifters do not interfere with one another while lifting.

The weight of the 228-pound I-shaped SACON block precludes two persons from lifting without exceeding the two-man, 112-pound human engineering design limits. The design weight limits are slightly exceeded when a four-man lift is utilized: 200 pounds versus a maximum recommended four-man lift of 196 pounds. The design weight values have to be modified for situations requiring repetitive lifting. If the frequency of lift exceeds 1 lift in 5 minutes or 20 lifts per 8 hours, the permissible weight limits are to be reduced. The reduction percentage is calculated by multiplying the lift frequency (i.e., lifts per minute) by 8.33. The installation and refurbishment of SACON barriers require repetitive lifting. For example, 32 full I-blocks (228 lb) and 32 half I-blocks (114 lb) must be lifted in about 2 hours to construct a barrier wall on one firing lane on the 25-Meter Range. Each member of the four-man crew would make 48 lifts in 120 minutes, which would result in a lift frequency of 0.4. The allowable design weight would be reduced by 3.33 percent in this scenario, making the maximum allowable four-man lift 190 pounds (86 kg).

The surface finish of SACON probably could be utilized to meet frictional grasp surface requirements (ref MIL-STD-1472E (ref 46)) when the blocks are dry. Problems ensuring a proper lifting surface could occur if the blocks become wet either naturally or to reduce the dust inhalation hazard as previously suggested.

The PPE recommended based on these data would include an appropriate respirator, steel-toed boots, safety glasses, leather gloves, and coveralls.

Figure 5-17. Four-man lift - 200-pound SACON block.

Figure 5-18. Two-man lift - 100-pound SACON block.

5.1.9 Objective 4.1. Assess the maintainability of the SACON bullet traps.

Data. Qualitative data were collected to assess the maintainability of SACON bullet traps. During the demonstration, Range Supervisors were asked the following: Compared to other firing lanes, SACON provides a marked reduction in range downtime. The responses are presented as Figure 5-19.

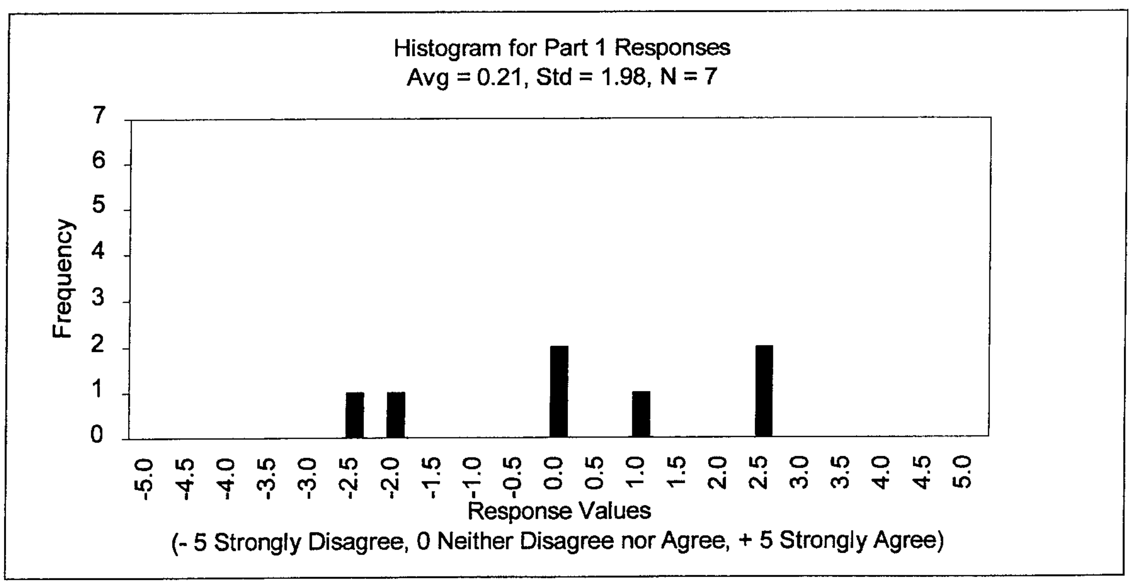


Figure 5-19. Range Inspection Survey maintainability responses.

At the conclusion of the demonstration, the Fort Knox Range Supervisors were asked the following questions related to maintainability:

(1) Are there any maintenance problems associated with the use of SACON?

(2) In your opinion, were the SACON firing lanes more difficult, easier, or the same to maintain? Explain.

(3) In your opinion, how did the maintenance operations involving SACON differ from standard maintenance operations?

The responses varied by range type. The Fort Knox CPQC Range Supervisor indicated the frequent shifting of the blocks at the second target as a maintenance problem. Durability of the 70-lb/ft^3 SACON blocks at the second target position was reduced by its proximity (16 m) to the shooter. In general, the Range Supervisor stated that the SACON firing lanes were easier to maintain. He attributed this to the fact that the blocks were test cases and thus were maintained less frequently to determine wear rates. This seems to indicate the blocks may be changed out more frequently in actual use. Maintenance differed using SACON in that PPE became an issue. The maintenance of used SACON creates the potential for lead inhalation exposure and requires the use of PPE to mitigate the hazard (para 5h). This differed from procedures previously employed to maintain wooden barriers. Total lead concentrations have also been measured in wooden barrier debris. It is unclear whether the PPE required for the maintenance of SACON should differ from the PPE required to maintain traditional wooden structures. Lead inhalation would appear to be an issue when disturbing the soil around the wooden barriers during maintenance (ref 9).

The Fort Knox ARF Range Supervisor indicated the weight of the individual blocks and the associated dust made the blocks extremely difficult to rotate and manipulate. This comment substantiates the lifting and handling analysis presented in paragraph 5h. The supervisor stated the effect upon berm maintenance was "fantastic". He estimated berm maintenance was about one-third of that for the standard dirt berm. He indicated in general that more maintenance was required for SACON backstops than for logs and that a forklift was required to complete the work.

The Fort Knox AFF Range Supervisor commented that the destruction of one or two blocks in the stack requires the reconstruction of the whole pile. The blocks were too heavy and the wire punctured the leather gloves. He indicated that the rearranging maintenance action requires many man-hours and personnel to perform.

The Fort Knox 25-Meter Range Supervisor commented that rearranging the blocks would be labor-intensive.

The USMA ARF Range Supervisor strongly agreed with the following statement: Compared to other firing points, SACON firing points are easily maintained.

Assessment. From the responses generated during the demonstration, it can be stated only that more persons agreed than disagreed with the following statement: Compared to other firing lanes, SACON provides a marked reduction in range downtime. From the comments by the Fort Knox Range Supervisors at the conclusion of the demonstration, several consistent maintainability conclusions can be made. The weights of the individual blocks were judged to be too heavy. Rearranging worn blocks is a labor-intensive operation and is necessitated by the failure of only two blocks within a large stack. Lead dust creates a potential for lead inhalation exposure and thus must be mitigated through PPE. The wire used in the manufacture of the steel-reinforced SACON produces debris which sometimes causes punctures through leather gloves, resulting in minor injuries to the range workers' hands when handling the debris. In general, more time was spent maintaining SACON backstops than in maintaining currently used materials. The exception was in using SACON in the berm in front of target positions on the ARF, AFF, and CPQC Ranges. An estimate of a two-thirds reduction in maintenance time for these berms was made by a Fort Knox Range Supervisor.

5.1.10 Objective 4.2. Assess the durability of the SACON bullet traps.

Data. Durability data on the original SACON formulation were generated at the USMA's Range 3 and Fort Knox's Canby Hill Range through normal training operations at these 25-Meter Ranges. Depth-of-penetration measurements were taken periodically and correlated with cumulative rounds fired from the firing position. The rounds fired versus depth-of-penetration data for USMA and Fort Knox 25-Meter Ranges are presented as Figures 5-20 and 5-21.

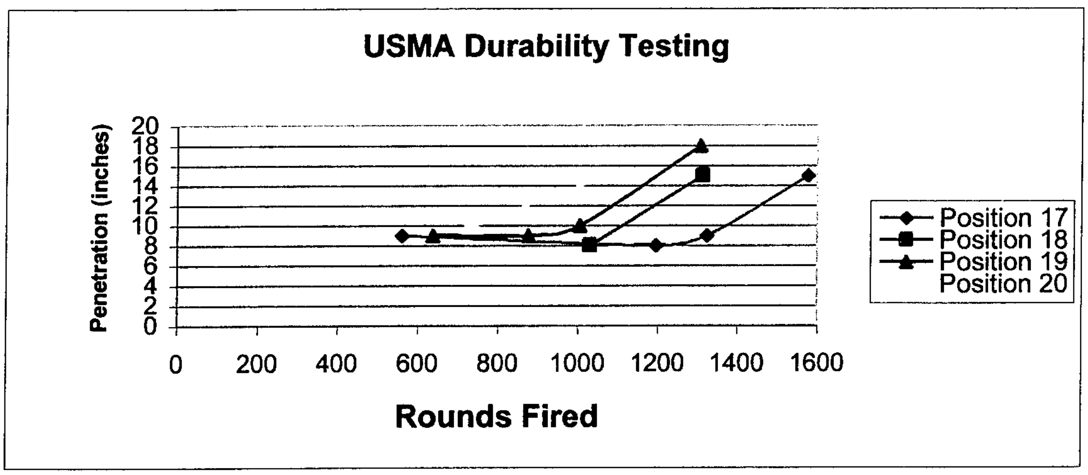


Figure 5-20. Rounds fired versus depth of penetration, USMA.

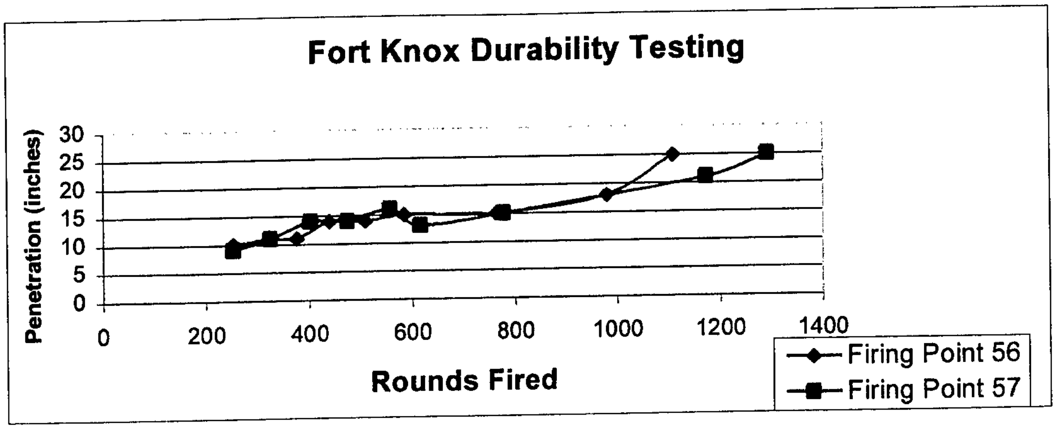


Figure 5-21. Rounds fired versus depth of penetration, Fort Knox.

An accelerated durability test was performed at ATC. Figure 5-22 graphically presents the depth-of-penetration versus rounds fired data for the recycled SACON variant. Figure 5-23 graphically presents the depth-of-penetration versus rounds fired data for the reformulated SACON variant. Figure 5-24 graphically presents the depth-of-penetration versus rounds fired data for the large SACON block variant.

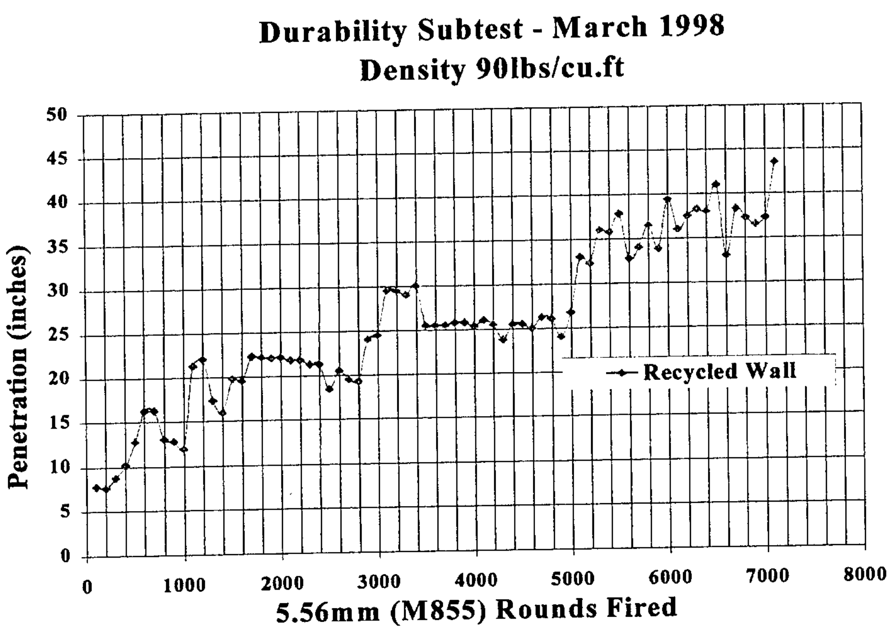


Figure 5-22. Recycled SACON - depth of penetration versus rounds fired.

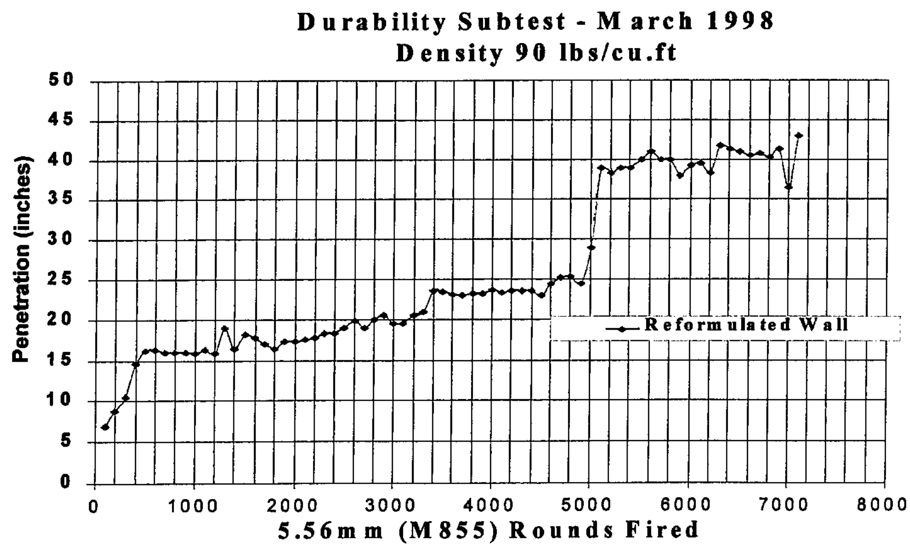


Figure 5-23. Reformulated SACON - depth of penetration versus rounds fired.

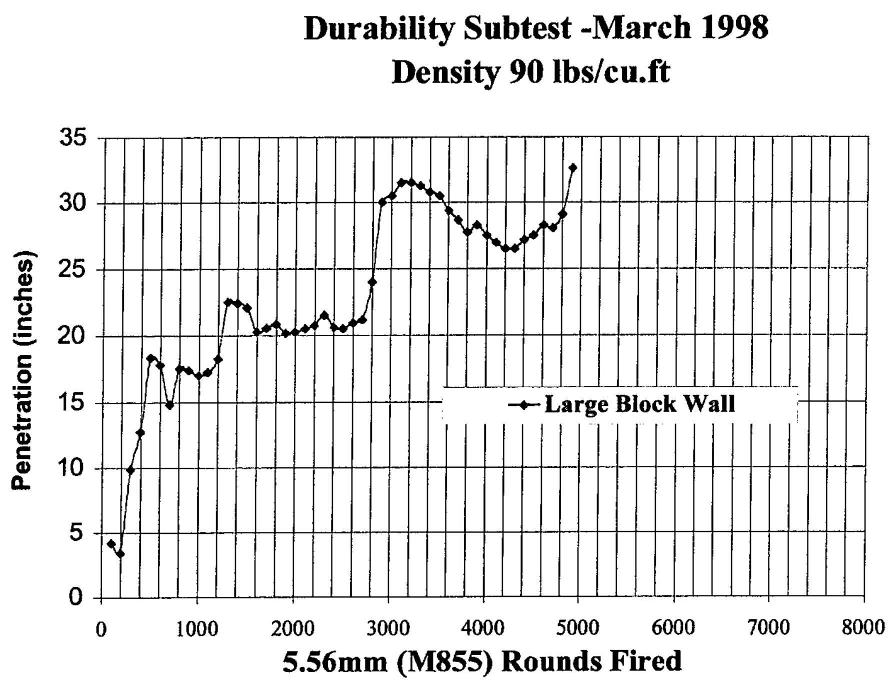


Figure 5-24. Large SACON block - depth of penetration versus rounds fired.

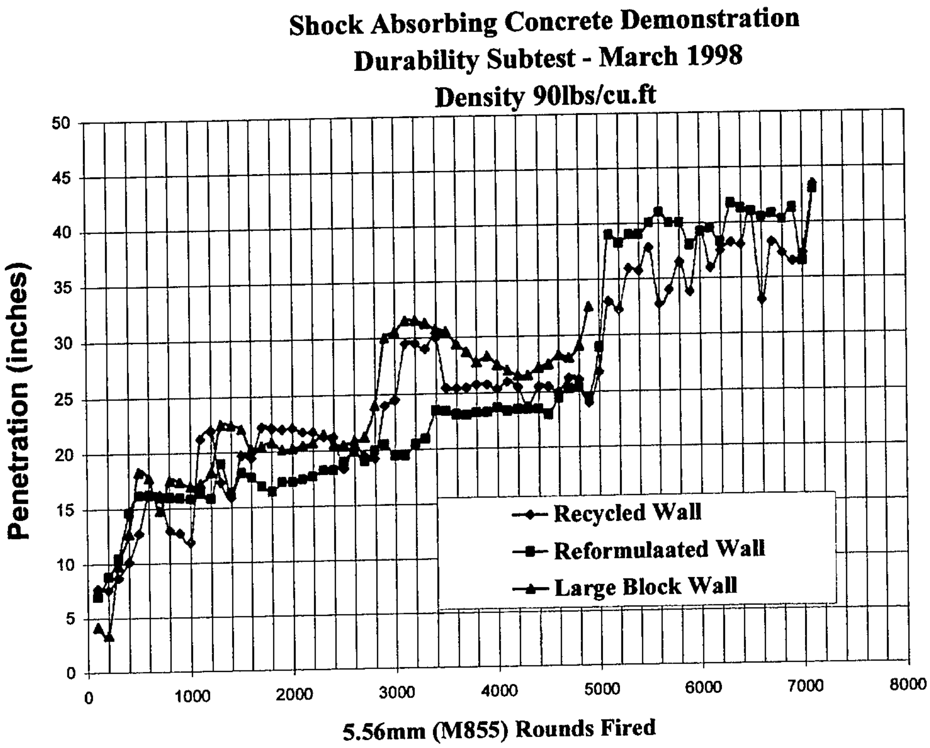


Figure 5-25. Depth-of-penetration versus round count comparison.

Assessment. Two firing positions exist at each firing lane as part of the normal operation of USMA's Range 3 and Fort Knox's Canby Hill Range. With the two-lane operation, two major cavities developed per barrier wall behind each of the paper targets. Round counts were collected for each firing position with the maximum depth of penetration in each barrier wall measured in periodic intervals. The curves presented in Figures 5-20 and 5-21 represent the deepest penetration in a firing position barrier wall in either of the two major cavities.

The accelerated durability test at ATC was used to develop SACON durability data when a 25-Meter Range SACON barrier was impacted to create a single cavity. This was done to determine a conservative number of rounds which a 25-Meter Range barrier could receive before a major maintenance action was required. Wear curves were developed for each of the three SACON variants tested at ATC.

In examining the wear curves presented in Figure 5-25, several trends are apparent. Rapid wear occurred through the first 16 inches of depth. This is not surprising since a single M855 round fired from an M16A2 rifle at Fort Knox penetrated 3 to 5 inches into a SACON block with a density of 90 lb/ft^3. After the initial growth of the cavity developed, a noticeable decrease in block wear was evident. The decreased wear rate has been attributed to an increasing wall density created by the accumulation of bullets and the compaction of SACON within the cavity. The walls had an irregular but increasing wear rate after the initial formation of the cavity. Rapid wear of the walls was observed between 5000 and 5100 rounds fired in both the recycled and reformulated walls. It is important to note that each of the I-blocks is 32 inches thick as measured in the center. Previous WES testing had shown that as bullet penetration approaches the rear of the block, spalling fractures occur that create susceptibility for rapid block failure. At 5000 rounds, the first column of the recycled wall had been penetrated to 84 percent of its depth. The first column of the reformulated wall had been penetrated to 90 percent of its depth. The explanation of the rapid wear exhibited during the accelerated durability shoot is complicated by the differing weather conditions placed upon the wall between the 5000- and 5100-shot group. The shooting of 5000 rounds was completed on 16 March 1998. The walls had not been exposed to rain up to this point. Between 16 and 23 March 1998, the test site received 3.6 inches of rain with a total of 0.35 inch falling the night of 22 March 1998. Both the reformulated and recycled walls were noticeably wet with the cavities containing a slurry mixture of debris.

Strength testing was conducted using procedures (in general conformance with American Society for Testing Materials (ASTM standards) on several SACON samples to determine the effect of wetting the blocks. Eight samples of reformulated SACON were saw-cut from a 24- by 32- by 6-inch block. The test samples were weighed and then four samples were immersed in water for four days to thoroughly soak the SACON. The soaked blocks were then reweighed to determine if saturation occurred or if the closed cell structure prevented the absorption of water. The samples were then compressed to failure with a 600,000-pound capacity tensile/compressive test machine. The blocks became heavier, indicating the uptake of water. The strength of the previously submerged blocks was approximately 25 percent less than that of the dry blocks (table 5-17).

TABLE 5-17. COMPARISON OF REFORMULATED SACON CHARACTERISTICS - WET VERSUS DRY

Sample No.	Weight, lb	Weight after Immersion, lb	Maximum Load, lb	Compressive Strength, psi
1	16.82	NA	42,300	1,249
2	17.34	NA	38,900	1,177
3	17.40	NA	44,500	1,313
4	17.44	NA	49,200	1,477
1A	17.56	18.60	35,300	1,051
2A	17.27	18.09	36,500	1,101
3A	17.97	18.79	29,800	851
4A	17.90	18.92	30,800	901

NA = Not applicable.

The test blocks absorbed as much as 1 pound of water in the four-day soaking process. This amounted to 450 mL for blocks No. 1A and 4A and indicates that the closed cell structure of SACON does not prevent water saturation. The test blocks not soaked in water had an average compressive strength of 1304 psi versus 976 psi for the water-immersed blocks. The wet SACON had a compressive strength 25 percent lower than that of the dry SACON. Since the compressive strength level of SACON correlates to the ease of bullet penetration, SACON becomes more easily penetrated when soaked.

A reduction of the wear rate after the 5000- to 5100-shot group occurred for both the reformulated and recycled walls. The rapid wear extended only 1 inch into the second row of recycled blocks and 7 inches into the second row of the reformulated blocks because of the elimination of spalling effects and because of the increased density created by debris remaining in the cavity.

Table 5-18 summarizes the wear rates through 8-inch increments of block depth. For the recycled and reformulated walls, 8 inches represented one-quarter of an individual block depth. For the large block wall, 8 inches represented one-third of an individual block depth. Of particular interest is the difference in wear rates through the column transition for the reformulated and recycled walls. From field observations, the reformulated wall was stacked "tighter" than the recycled wall. A reduction of distance between the columns appears to reduce the effects of spalling fractures and to create a more even wear rate.

TABLE 5-18. WEAR RATES VERSUS BLOCK DEPTH

SACON Variant	Wall Depth, in.					
	0 to 8	8 to 16	16 to 24	24 to 32	32 to 40	40 to 43
	Wear Rate, rd/in.					
Recycled	22.9	40.0	501.8	58.0	57.5	533.3
Reformulated	34.3	40.0	317.2	244.0	175.0	240.0
Large block	31.3	25.0	293.8	244.8	NA	NA

NA = Not applicable.

The durability data generated can be used to estimate the number of block rotations that will be necessary each year. A high-use 25-Meter Range shoots between 20,000 and 30,000 rounds from each firing point yearly (ref 4). Accelerated durability testing indicated that one firing cavity in either a reformulated or recycled SACON barrier can receive 7,100 rounds before a block rotation is necessitated. If SACON were to be utilized on a 25-Meter Range with each firing position shooting 30,000 rounds, a maximum of four block rotations per firing position would be required annually.

Demonstrated usage of the USMA 25-Meter Ranges showed an average of 1950 rounds fired from each firing point over a period of four months. This equates to a yearly usage rate of 7800 rounds per firing point. Range observations indicate that two prominent, distinct cavities develop behind the left and right target positions at each firing point. Additionally, smaller cavities are created near the base of the wall as a function of the training process. By equally distributing shooting between the left and right firing positions, the number of block rotations can be minimized. Using the annual rate extrapolated for USMA, assuming an equal distribution, and utilizing the wear rates generated by the accelerated durability testing at ATC, block rotations are estimated to be required every two years.

Demonstrated usage of the Fort Knox 25-Meter Ranges showed an average of 1170 rounds fired from each firing point over a period of three months. This equates to a yearly usage rate of 4680 rounds per firing point. Range observations again indicated that two prominent, distinct cavities developed behind the left and right target positions at each firing point. Additionally, smaller cavities were created near the base of the wall as a function of the training process. By equally distributing shooting between the left and right firing positions, the number of block rotations can be minimized. Using the annual rate extrapolated for Fort Knox, assuming an equal distribution, and utilizing the wear rates generated by the accelerated durability testing at ATC, block rotations are estimated to be required every three years.

5.1.11 Objective 5.1. Assess the distraction to the shooter caused by the SACON bullet traps.

Data. Each soldier who fired a weapon on a SACON-outfitted range was asked to complete a training realism survey. Three questions relating to range distraction were asked:

(1) The size and location of the SACON barrier are not significant distractions to the firer.

(2) The color and texture of the SACON barrier are not significant distractions to the firer.

(3) Rounds impacting (noise or dust) the SACON barrier are not significant distractions to the firer.

Figures 5-26 through 5-31 are presented to summarize the responses to these questions.

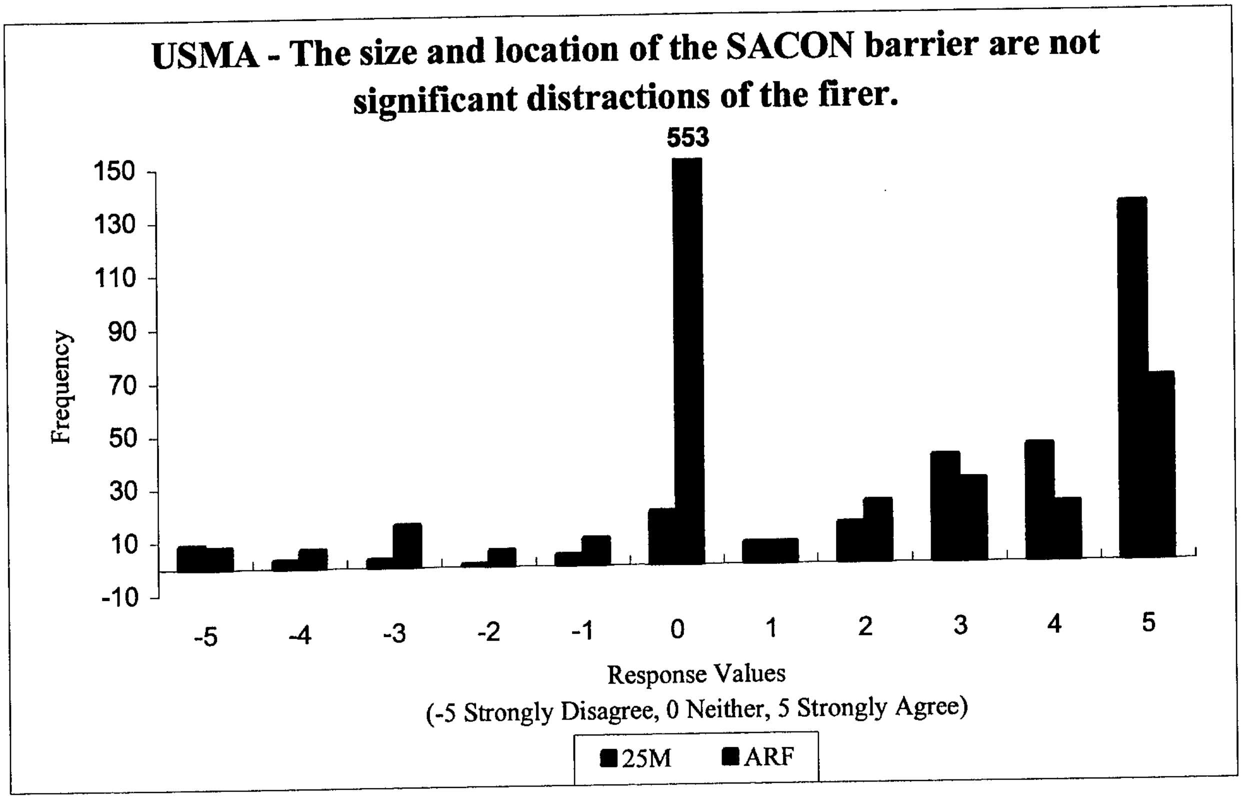


Figure 5-26. USMA range distraction - size and location.

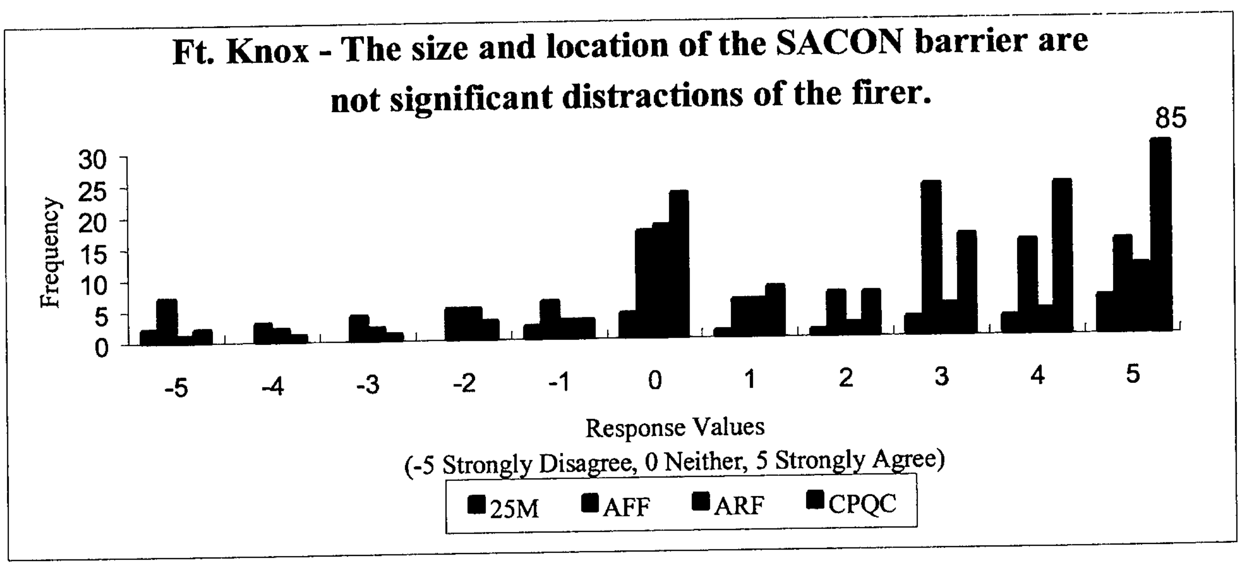


Figure 5-27. Fort Knox range distraction - size and location.

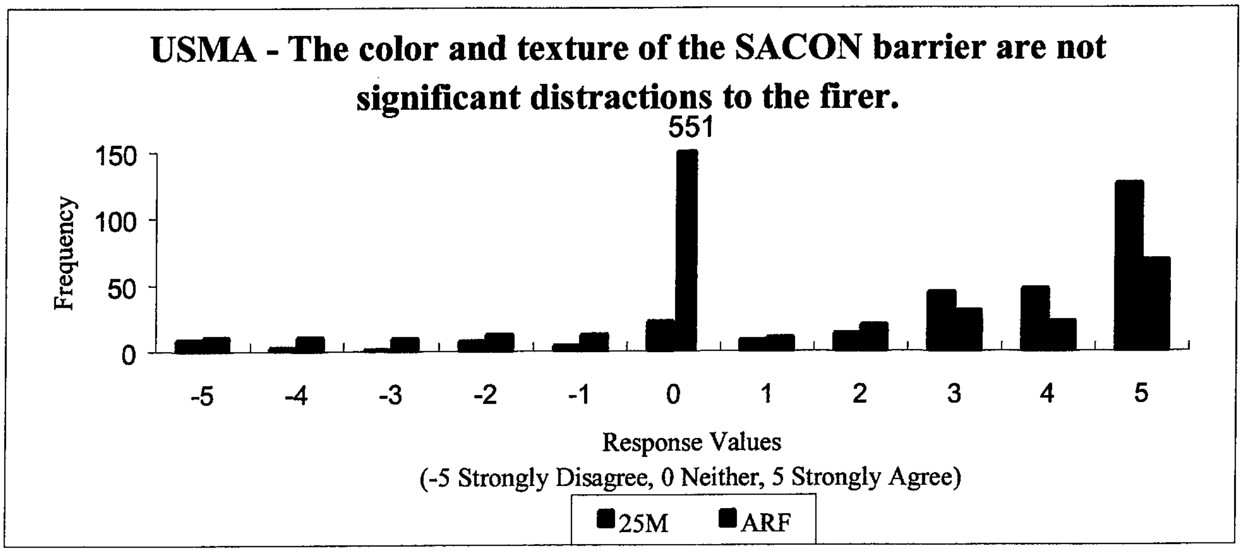


Figure 5-28. USMA range distraction - color and texture.

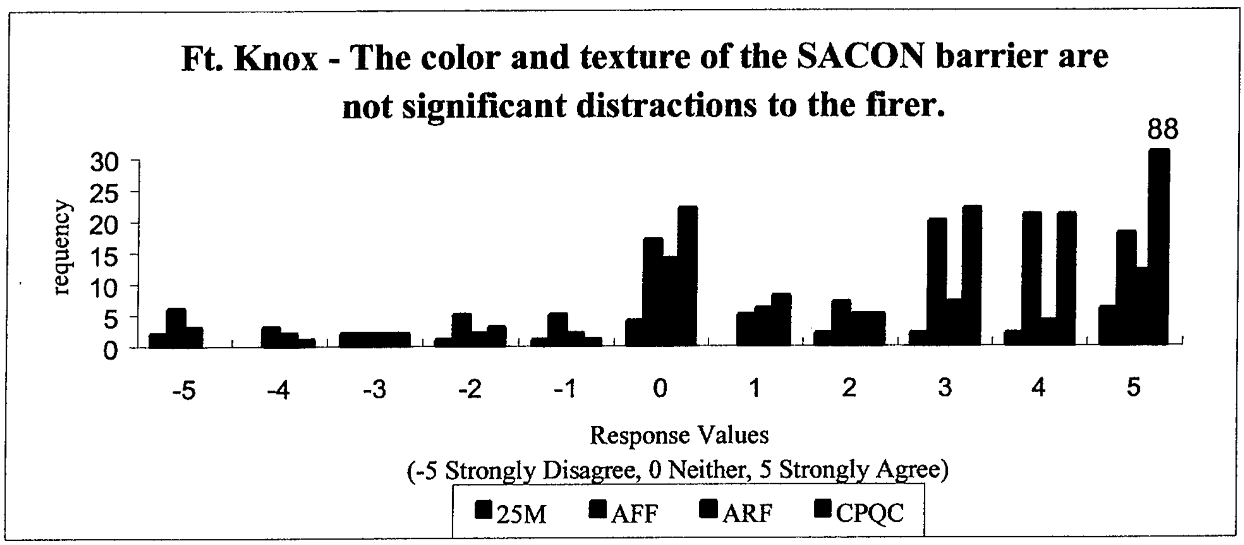


Figure 5-29. Fort Knox range distraction - color and texture.

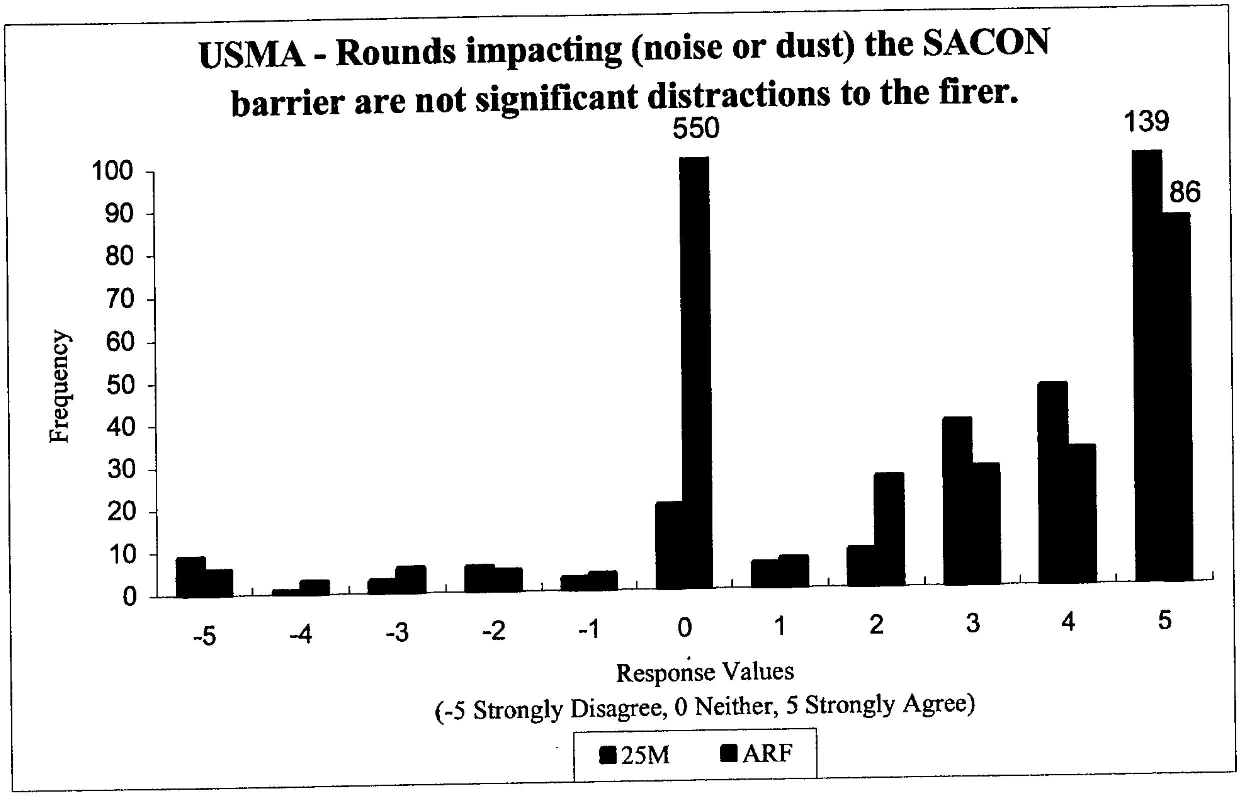


Figure 5-30. USMA range distraction - noise or dust.

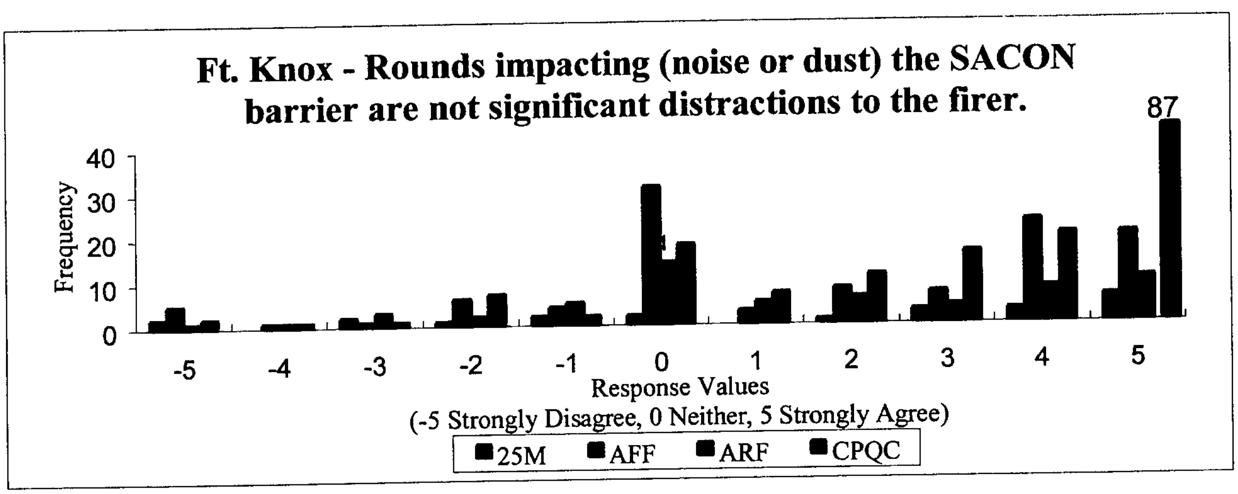


Figure 5-31. Fort Knox range distraction - noise or dust.

Assessment. The average response to the question "The size and location of the SACON barrier are not significant distractions to the firer" was positive for all ranges, indicating a general agreement. The size and location of SACON barriers were not a significant distraction to the shooter (table 5-19).

TABLE 5-19. SUMMARY - SACON SIZE AND LOCATION

	Fort Knox Avg	Std	N	USMA Avg	Std	N
25 M	1.91	3.10	22	3.32	2.46	281
AFF	1.39	2.95	109	-	-	-
ARF	1.08	2.71	59	0.59	1.89	756
CPQC	3.27	2.33	173	-	-	-

N = Number of responses.
Std = Standard.

The color and texture of the SACON barrier were not significant distractions to the firer (table 5-20).

TABLE 5-20. SUMMARY - SACON COLOR AND TEXTURE

	Fort Knox Avg	Std	N	USMA Avg	Std	N
25 M	1.32	3.40	22	3.26	2.43	282
AFF	1.74	2.90	109	-	-	-
ARF	1.32	2.89	59	0.55	1.91	753
CPQC	3.42	2.14	173	-	-	-

Rounds impacting (noise or dust) the SACON barrier were not significant distractions to the firer (table 5-21).

TABLE 5-21. SUMMARY - SACON NOISE OR DUST

	Fort Knox Avg	Std	N	USMA Avg	Std	N
25 M	1.50	3.47	22	3.37	2.47	282
AFF	1.69	2.78	109	-	-	-
ARF	1.42	2.64	59	0.83	1.92	753
CPQC	3.25	2.39	173	-	-	-

5.1.12 Objective 5.2. Assess the down-range visibility impact caused by SACON.

Data. Each soldier who fired a weapon on a SACON-outfitted range was asked to complete a training realism survey. Two questions relating to down-range visibility were asked:

(1) The SACON's size does not impact your visibility of down-range targets.

(2) The SACON's location does not impact your visibility of down-range targets.

Figures 5-32 through 5-35 are presented to summarize the responses to these questions.

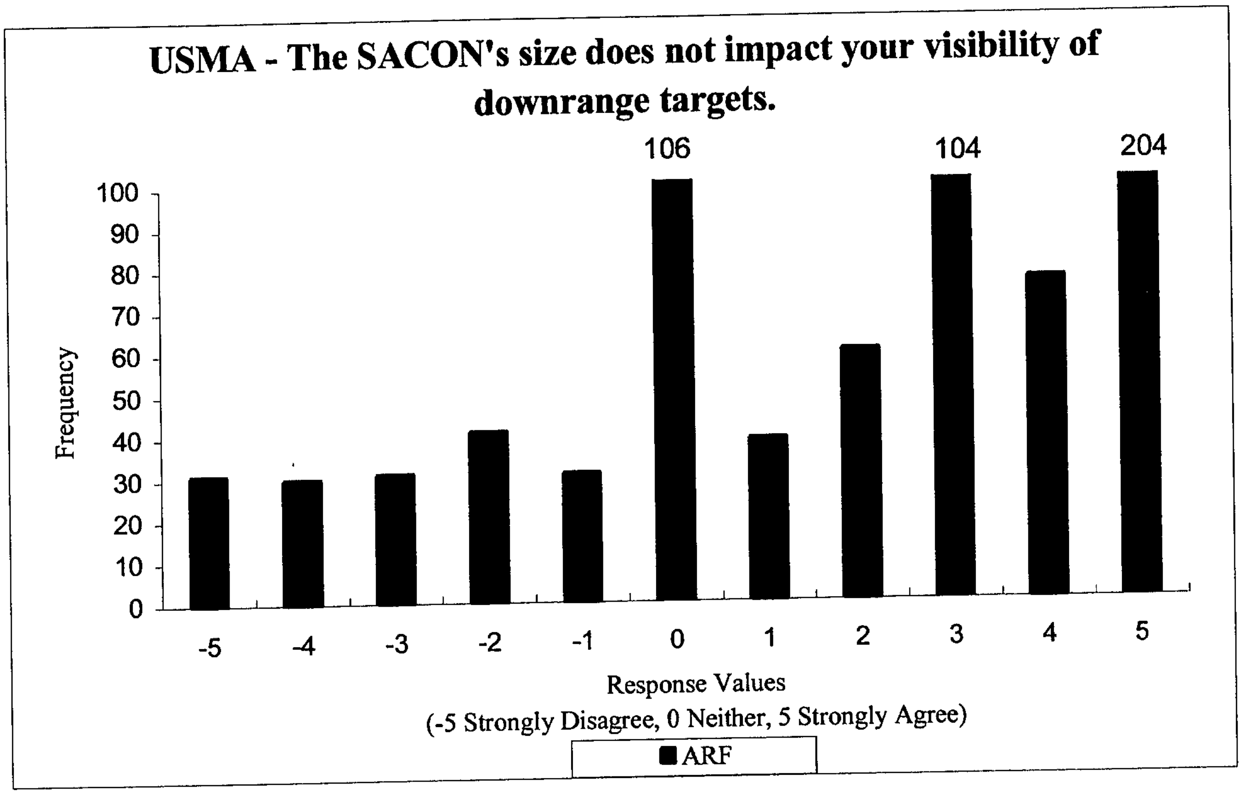


Figure 5-32. USMA down-range visibility - size.

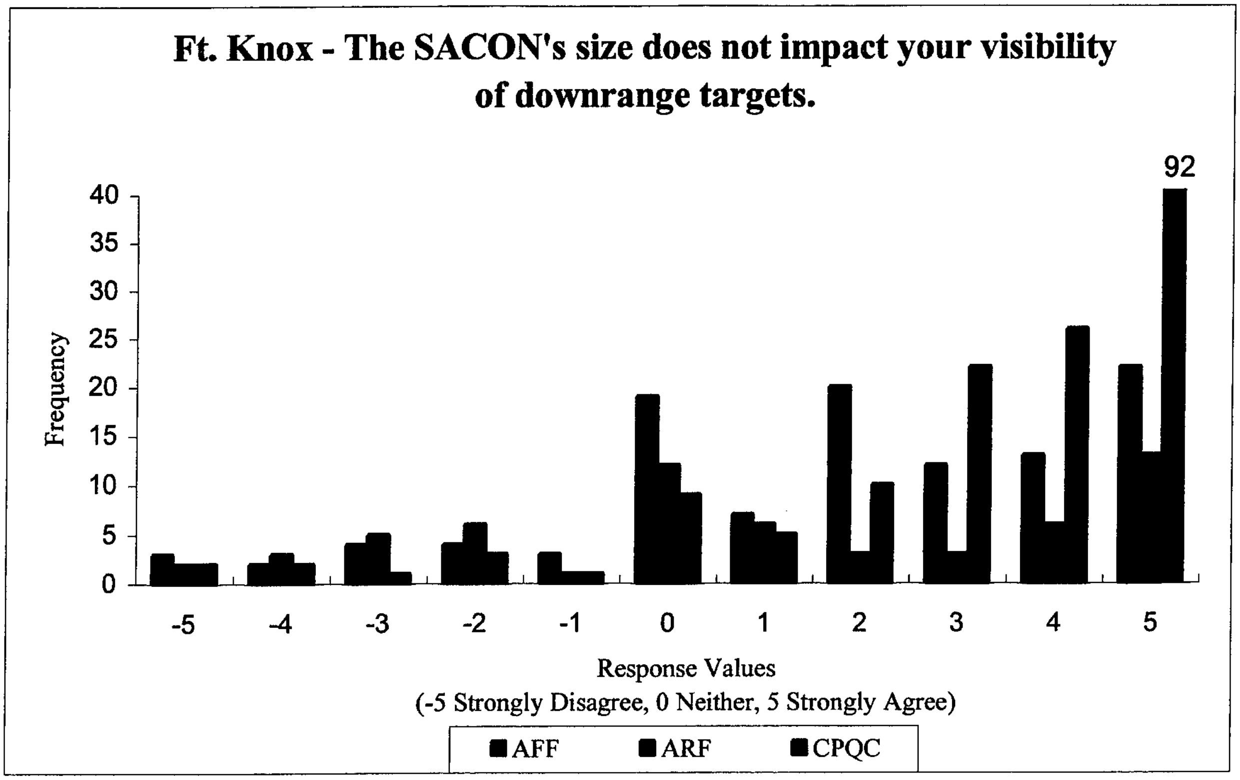


Figure 5-33. Fort Knox down-range visibility - size.

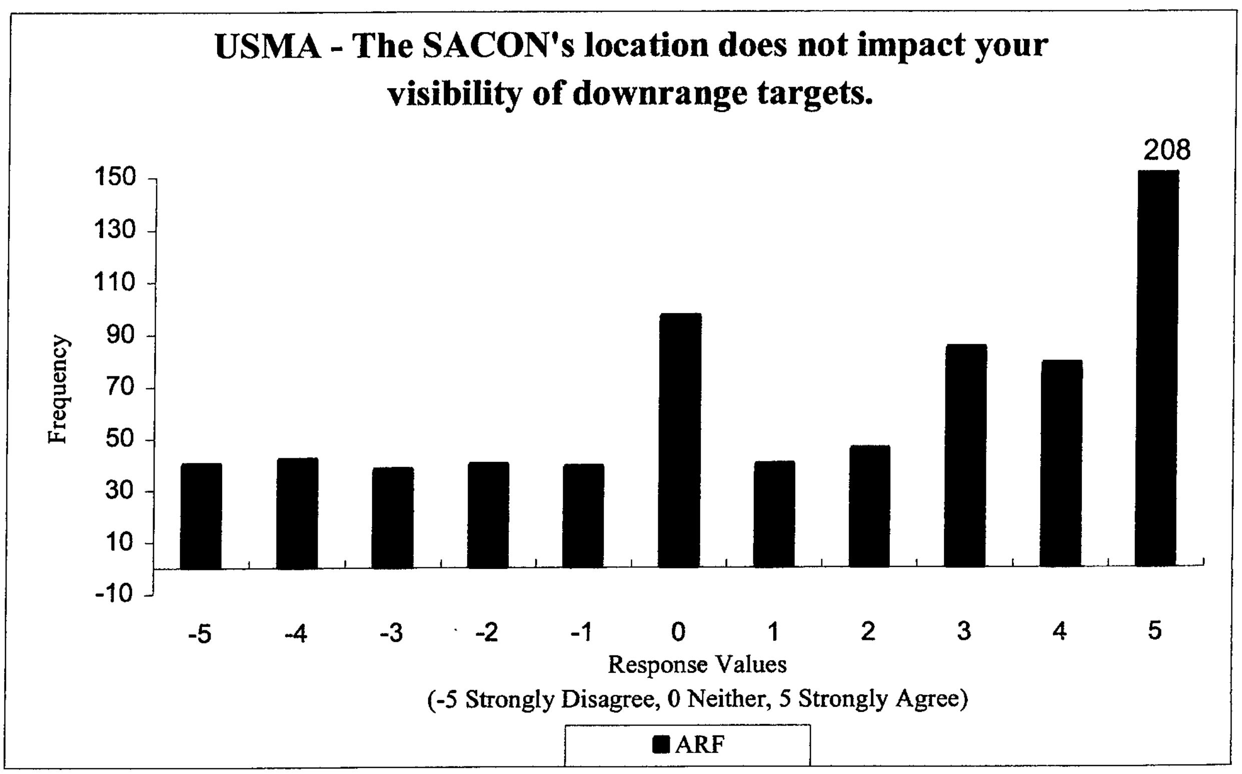


Figure 5-34. USMA down-range visibility - location.

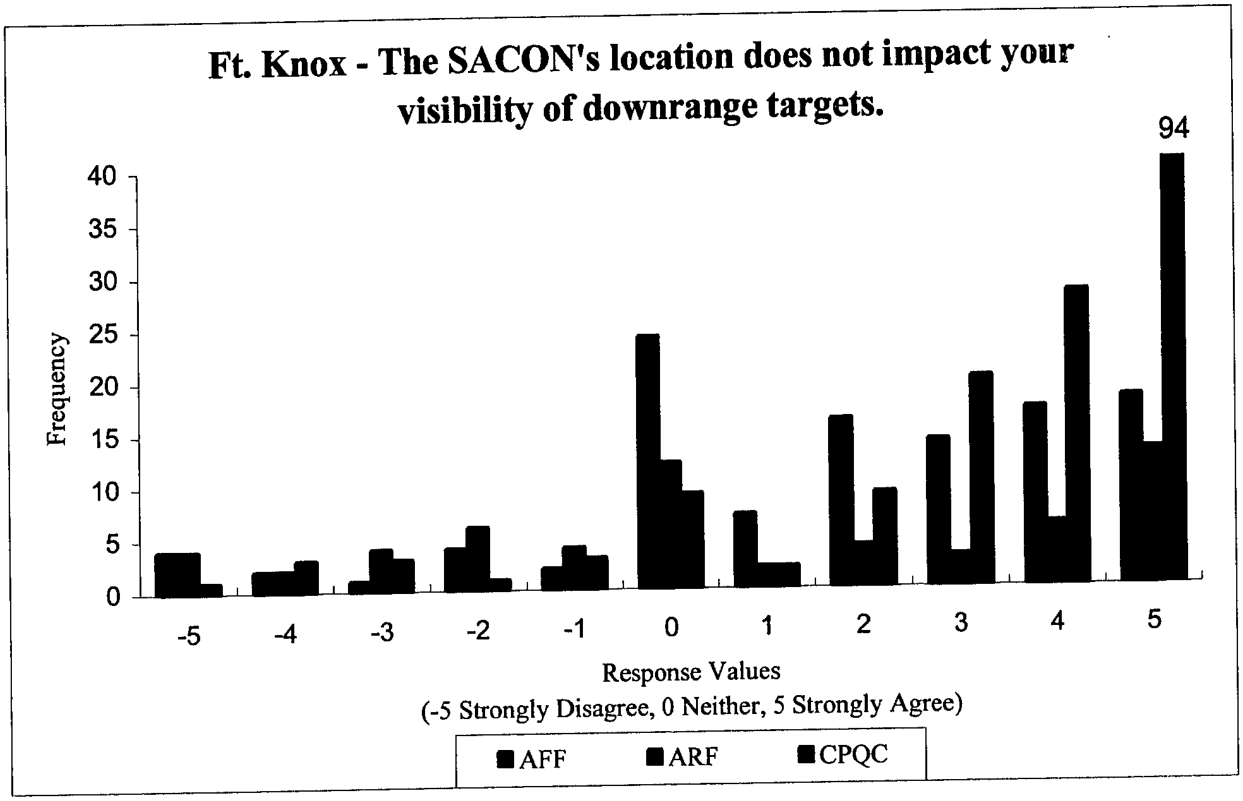


Figure 5-35. Fort Knox down-range visibility - location.

Assessment. The SACON's size did not impact the visibility of down-range targets (table 5-22).

TABLE 5-22. SUMMARY - SACON SIZE EFFECT ON VISIBILITY

	Fort Knox Avg	Std	N	USMA Avg	Std	N
AFF	1.83	2.64	109	-	-	-
ARF	1.00	3.12	60	1.75	3.04	753
CPQC	3.62	2.14	173	-	-	-

The SACON's location did not impact the visibility of down-range targets (table 5-23).

TABLE 5-23. SUMMARY - SACON LOCATION EFFECT ON VISIBILITY

	Fort Knox Avg	Std	N	USMA Avg	Std	N
AFF	1.82	2.58	109	-	-	-
ARF	0.87	3.23	60	1.51	3.25	754
CPQC	3.65	2.19	173	-	-	-

5.1.13 Objective 5.3. Assess the ability of the SACON to conceal target locations.

Data. Each soldier who fired a weapon on a SACON-outfitted range was asked to complete a training realism survey. Two questions relating to target concealment were asked:

(1) The size and location of the SACON around the target do not significantly aid target identification.

(2) The color and texture of the SACON around the target do not significantly aid target identification.

Figures 5-36 through 5-39 are presented to summarize the responses to these questions.

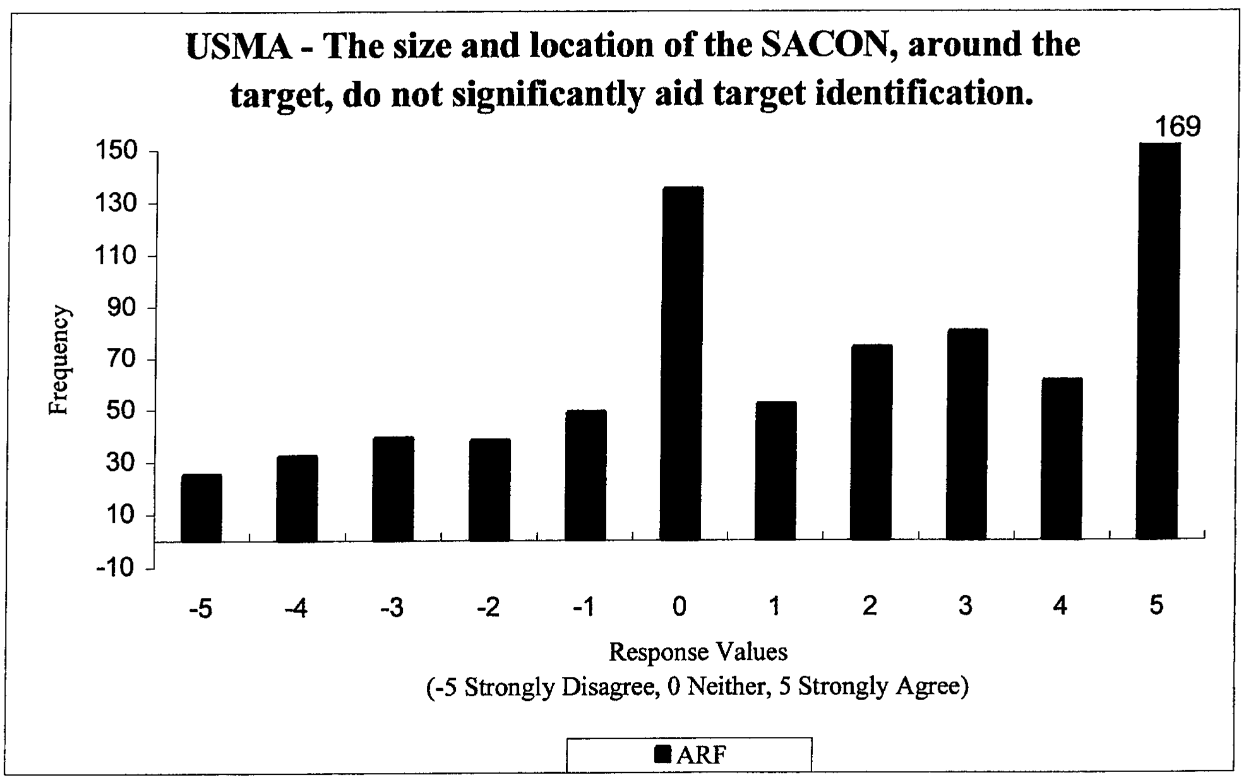


Figure 5-36. USMA target concealment - size and location.

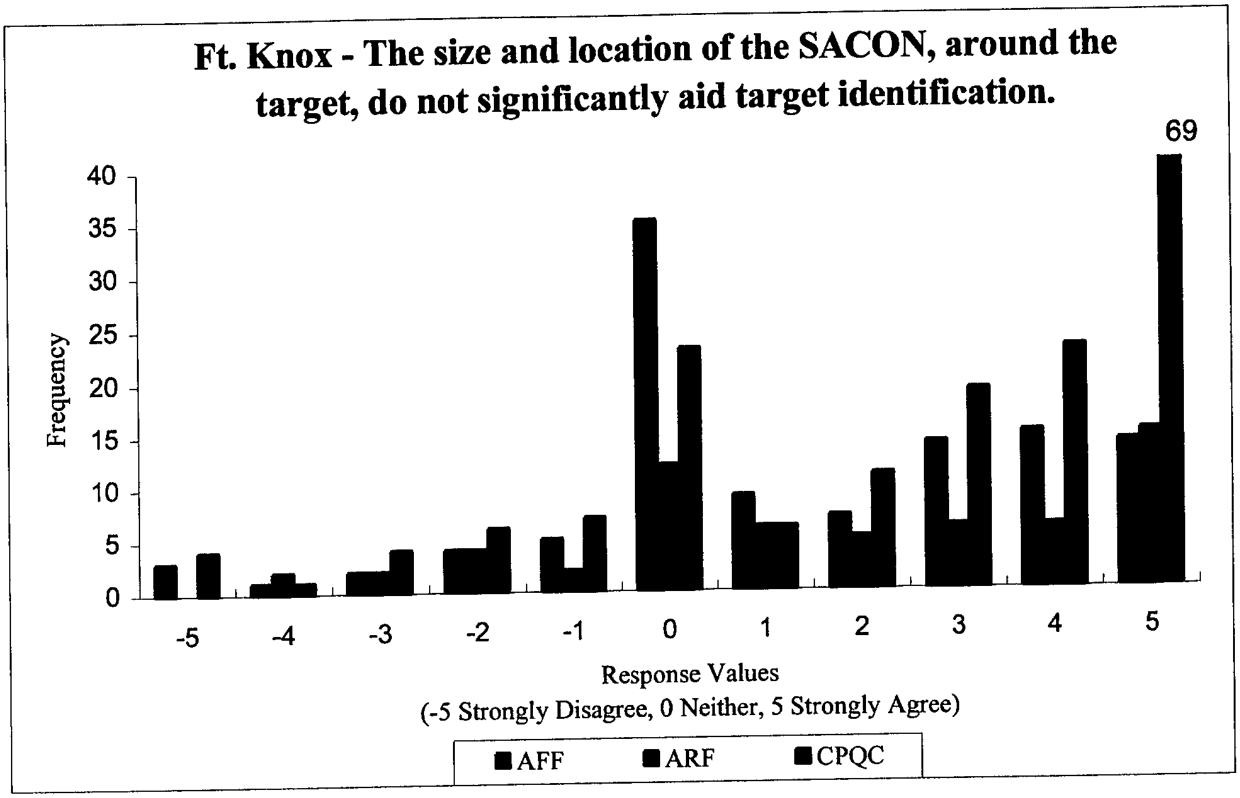


Figure 5-37. Fort Knox target concealment - size and location.

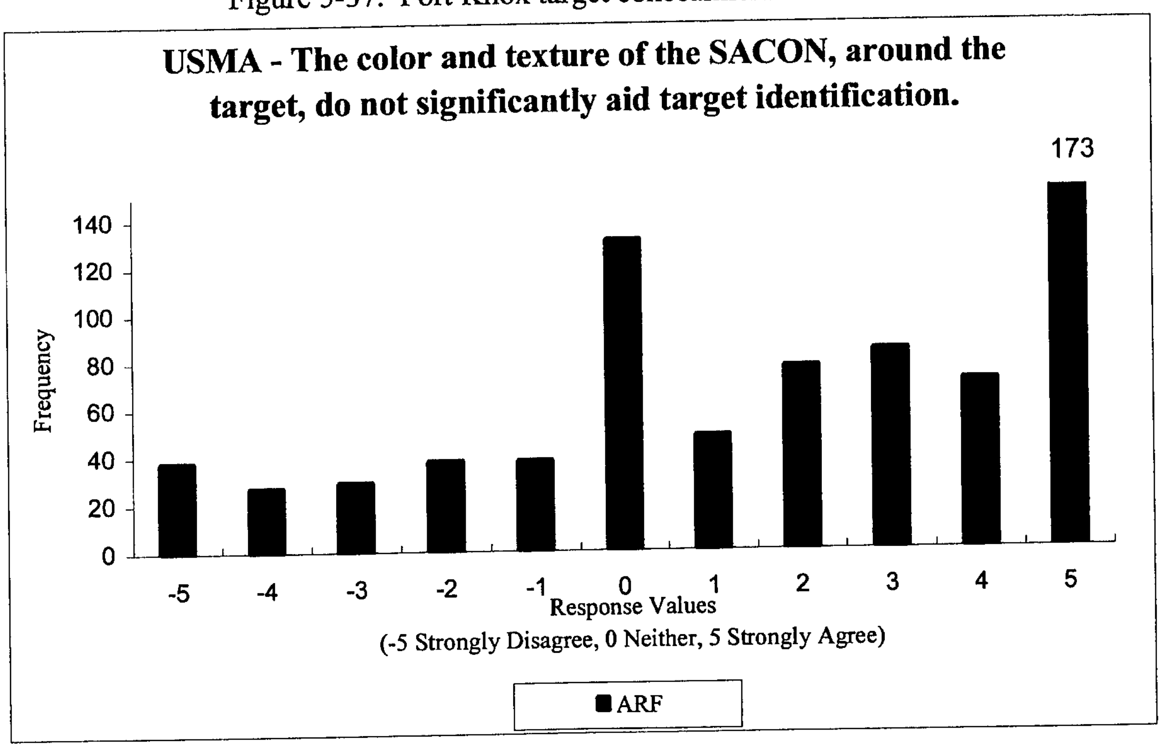


Figure 5-38. USMA target concealment - color and texture.

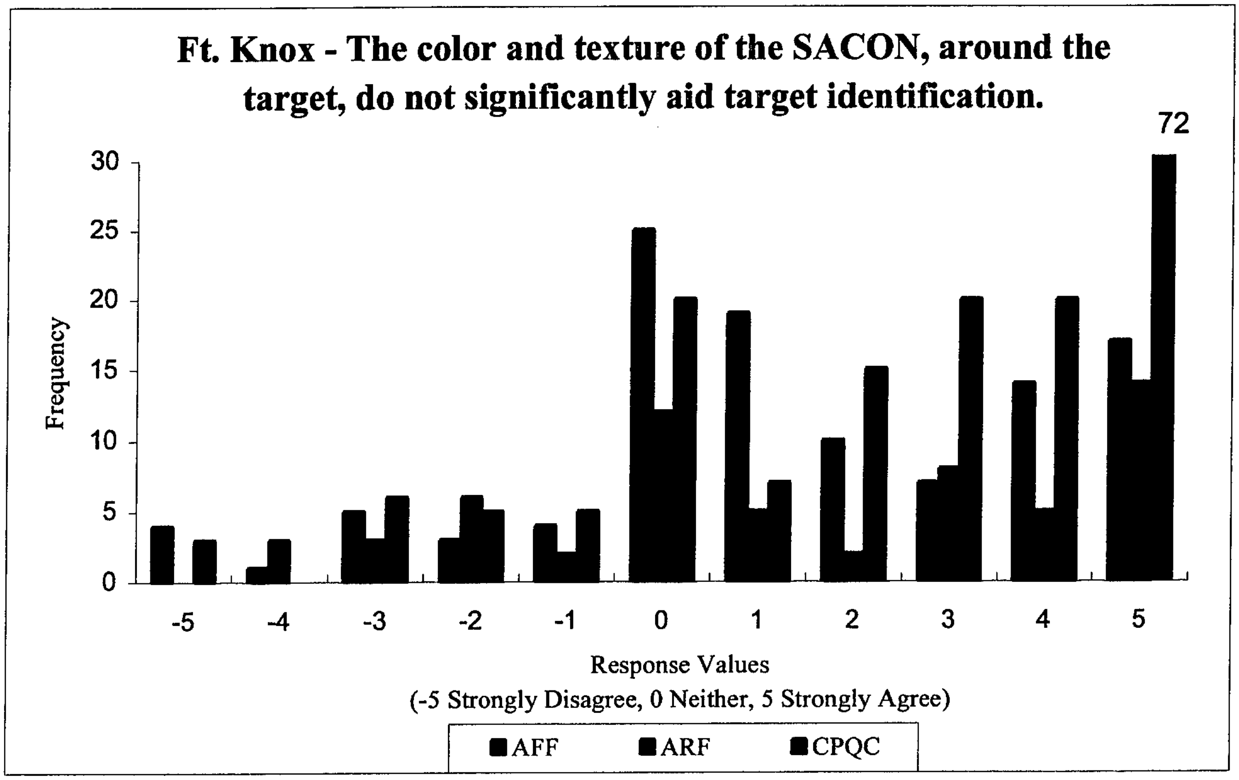


Figure 5-39. Fort Knox target concealment - color and texture.

Assessment. The size and location of the SACON around the target do not significantly aid target identification (table 5-24).

TABLE 5-24. SUMMARY - SACON SIZE AND LOCATION EFFECT ON TARGET IDENTIFICATION

	Fort Knox Avg	Std	N	USMA Avg	Std	N
AFF	1.44	2.47	109	-	-	-
ARF	1.82	2.67	60	1.37	2.95	754
CPQC	2.70	2.68	173	-	-	-

The SACON's color and texture do not impact visibility of down-range targets (table 5-25).

TABLE 5-25. SUMMARY - SACON COLOR AND TEXTURE EFFECT ON TARGET VISIBILITY

	Fort Knox Avg	Std	N	USMA Avg	Std	N
AFF	1.82	2.58	109	-	-	-
ARF	0.87	3.23	60	1.51	3.25	754
CPQC	3.65	2.19	173	-	-	-

5.1.14 Objective 6.1. Determine the ability to remove steel penetrators and/or steel fibers.

Data. Data were collected to determine an iron removal percentage. Composite samples of the crushed SACON were taken prior to the magnetic separation process. Composite samples were also taken after the blending of the recycled aggregate. Table 5-26 presents the results of lead, copper, iron, and zinc analyses for these samples.

TABLE 5-26. RECYCLING DATA, STEEL REMOVAL EFFICIENCY

WES No.	Process Sample	Total, mg/kg			
		Pb	Cu	Fe	Zn
2273-1	Before magnetic separation	100.00	<10.0	10,109.00	55.97
2273-2	Before magnetic separation	47.35	<10.0	8,240.91	43.94
2273-3	Before magnetic separation	71.96	<10.0	9,300.39	50.59
Average	Before magnetic separation	73.10	<10.0	9,216.77	50.17
2266-1	Blended aggregate	446.85	<10.0	6,318.21	47.55
2266-2	Blended aggregate	89.88	27.58	8,612.50	62.50
2266-3	Blended aggregate	117.05	18.20	8,121.07	59.00
2266-4	Blended aggregate	147.35	67.46	8,712.43	68.19
2266-5	Blended aggregate	163.40	11.17	8,653.79	65.34
2266-6	Blended aggregate	211.81	<10.0	8,985.59	70.40
2266-7	Blended aggregate	131.20	<10.0	8,675.40	65.00
2266-8	Blended aggregate	111.31	<10.0	8,861.51	68.65
2266-9	Blended aggregate	110.67	<10.0	6,982.29	52.10
2266-10	Blended aggregate	93.27	<10.0	7,647.58	60.23
2266-11	Blended aggregate	88.22	<10.0	6,439.52	50.20
2266-12	Blended aggregate	971.00	117.00	10,100.00	63.40
2266-13	Blended aggregate	1,351.60	304.69	7,599.20	81.54
2266-14	Blended aggregate	1,597.52	118.75	9,071.83	72.62
2266-15	Blended aggregate	2,294.27	210.09	9,325.98	78.38
2266-16	Blended aggregate	877.43	112.19	8,911.81	73.33

TABLE 5-26 (CONT'D)

WES No.	Process Sample	Total, mg/kg			
		Pb	Cu	Fe	Zn
2266-17	Blended aggregate	12,770.54	41,300.00	7,287.75	3,973.33
2266-18	Blended aggregate	2,129.35	2,474.47	9,240.34	320.36
2266-19	Blended aggregate	2,321.11	351.59	8,213.32	79.27
2266-20	Blended aggregate	752.91	179.96	9,163.39	84.15
Average	Blended aggregate	1,338.84	3,484.09	8,346.18	274.78

Pb = Lead.
Cu = Copper.
Fe = Iron.
Zn = Zinc.

Assessment. A removal percentage of 9.5 was derived using the average iron concentration before magnetic separation (9216.77 mg/kg) and the average iron concentration after reconstituting the aggregate (8346.18 mg/kg). Iron is a measurable commodity in portland cement with concentrations of 3 percent typical (Properties of Concrete, A.M. Neville, 1973). This, along with difficulties in collecting homogeneous samples, cast doubt on the validity of the removal percentage. However, WES observed penetrators in the blended aggregate. It appears that the 95-percent removal criterion was not met. The 95-percent criterion was developed by WES to reduce ricochet potential. No ricochets were observed during the accelerated durability shoot at ATC. The line-of-fire was perpendicular (90°) to the barrier during this test. The steel penetrators are less than 3/8 inch in size and would otherwise be allowable in the aggregate mix. Additional ricochet testing should be conducted to determine if removal of the penetrators is necessary.

5.1.15 Objective 6.2. Determine the ability to reduce toxicity characteristics.

Data. In order to evaluate the reduction of lead toxicity, composite samples were withdrawn from the recycling process immediately before magnetic separation. At the conclusion of the recycling event, a SACON test cylinder was poured. After curing, the cylinder was crushed and analyzed using the TCLP method. The TCLP lead concentrations are presented in Table 5-27.

TABLE 5-27. RECYCLING DATA - TOXICITY REDUCTION

WES No.	Process Sample	Total Pb, mg/kg	TCLP Pb, ppm
2273-1	Before magnetic separation	100.00	<0.10
2273-2		47.35	< .10
2273-3		71.96	< .10
Average		73.10	< .10
2276.00	Test cylinder	511.00	.86

Assessment. An examination of the results indicates a negative toxicity reduction. These results are not plausible in that no lead sources exist in the materials mixed with the recycled aggregate to form SACON. Nonhomogeneity of the samples is the likely cause of the faulty results. While the results are inconclusive, it appears that a significant amount of fine lead particles were present and passed through the sieve set. The crushing process was intended to flatten the M855 bullet slugs to ensure removal by the 3/8-inch sieve. WES's visual observations of the blended aggregate negated this assumption.

5.1.16 Objective 6.3. Determine the ability to contain and control lead.

Data. Personnel air monitoring was done by WES to measure particulates and lead in the breathing zone. The data are presented in Tables 5-35 and 5-36. Wipe samples were taken by WES after the breaking phase of the recycling processes. The analysis results of the wipe samples are presented in Table 5-28.

TABLE 5-28. RECYCLING PROCESS - SURFACE WIPE SAMPLES, 17 OCTOBER 1998, SACON BREAKING (JACKHAMMER)

Sample Location	Sample No.	Lead Concentration, mg/kg
Jackhammer	WW970102	1000
On pad/plastic (upwind)	WW970103	600
On pad/plastic (downwind)	WW970104	490
On pad/plastic	WW970105	200
On pad/plastic	WW970106	71

Assessment. Fugitive lead dust emissions were measured in both personnel breathing zone samples and the wipe samples from the area adjacent to the SACON breaking process. The wipe samples cannot be compared to the stated criteria because the surface area of the wiped area was not recorded. However, it is apparent that, over time, lead would accumulate on the surfaces surrounding the recycling operation. Unconfined recycling operations would eventually contaminate the recycling site. Proper facilities and precautions similar to those required for sandblasting would need to be utilized to ensure environmental compliance with the Clean Air Act.

5.1.17 Objective 6.4. Determine if the waste material generated is a hazardous waste.

Data. Samples of various waste components of the entire waste stream were taken by WES to be analyzed by ATC. The sample results of the components are presented in Table 5-29. A composite sample was taken by Defense Reutilization and Marketing Office (DRMO) for use in characterizing the entire recycling waste stream. The composite sample (No. 806336) was analyzed by American Environmental Services, Incorporated. The TCLP lead result was less than the detection limit of 0.05 mg/L.

TABLE 5-29. RECYCLING WASTE PRODUCTS - WASTE CHARACTERIZATION RESULTS

Sample No.	WES No.	Description	Total Lead, mg/kg	TCLP Lead, mg/L
21284	2271-1	Lead No. 8 fraction	170.62	<0.10
21285	2271-2		41.54	.33
21286	2270-1	Lead No. 4 fraction	28.67	< .10
21287	2270-2		4.37	< .10
21288	2275-1	Lead post sieve 576 No. block	685.26	< .10
21289	2268-1	Lead fine fraction	195.22	< .10
21290	2269-1	No. 100 fraction	82.16	< .10
21291	2274-1	Lead No. 8 material 576 No. block	356.25	< .10
21292	2272-1	Lead plus 1 in.	25.10	< .10
21293	2272-2		13.37	< .10
21294	2272-3		331.90	< .10

Assessment. The waste fractions showed significant concentrations of total lead. Using the rule of thumb, these waste products would be likely to exceed the 5-ppm RCRA hazardous waste criterion. However, none of the results exceeded 5 ppm with the highest measured result being 0.33 ppm. The analytical results of the waste materials indicate the waste products are an RCRA solid waste.

5.1.18 Objective 6.5. Determine the ability to generate a usable fine aggregate.

Data. The WES took composite samples of the blended aggregate. The ATC sieved the samples at laboratory scale to determine whether the recycling process produced an aggregate that complied with the *Technical Specification For Shock-Absorbing Concrete (SACON)* (ref 10). Table 5-30 provides size-grading comparisons of fine aggregates necessary for conformance with ASTM C 33-93 and ASTM C 144-89. Table 5-31 provides results of sieving the blended aggregate produced by the recycling operation.

TABLE 5-30. SIZE-GRADING COMPARISON FOR FINE AGGREGATES SPECIFIED IN ASTM C 33 AND ASTM C 144

ASTM C 33			ASTM C 144, % Passing	
Sieve Specification		% Passing	Natural Sand	Manufactured Sand
3/8-in.	9.5 mm	100	-	-
No. 4	4.75 mm	95 to 100	100	100
No. 8	2.36 mm	80 to 100	95 to 100	95 to 100
No. 16	1.18 mm	50 to 85	70 to 100	70 to 100
No. 30	600 μm	25 to 60	40 to 75	40 to 75
No. 50	300 μm	10 to 30	10 to 35	20 to 40
No. 100	150 μm	2 to 10	2 to 15	10 to 25
No. 200	75 μm	-	-	0 to 10

TABLE 5-31. SIEVE RESULTS, BLENDED AGGREGATE

Recycling Percent Passing Sieve Size after Blending of Aggregate							
Trial No.	9.5 mm	No. 4	No. 8	No. 16	No. 30	No. 50	No. 100
Percentage of Total Mass Passing Through Sieve							
1	89	86	86	71	51	23	3
2	89	86	86	68	45	20	2
3	91	90	89	74	48	23	5
4	93	90	90	76	55	27	2
5	92	90	89	74	48	22	3
6	88	84	84	68	46	20	3
7	90	86	85	68	44	20	7
8	88	84	84	70	41	16	2
9	90	86	86	73	48	24	4
10	90	86	86	70	45	19	3
11	90	86	86	75	42	21	5
12	91	87	86	76	41	21	4
13	93	90	90	80	42	22	4
14	93	91	90	82	40	23	6

TABLE 5-31 (CONT'D)

Recycling Percent Passing Sieve Size after Blending of Aggregate							
Trial No.	9.5 mm	No. 4	No. 8	No. 16	No. 30	No. 50	No. 100
15	95	93	92	83	35	18	4
16	93	90	90	80	33	17	4
17	93	90	90	80	35	17	3
18	92	89	89	80	35	19	4
19	95	92	92	84	40	22	5
20	91	88	88	79	41	26	7
Average	91	88	88	76	43	21	4
ASTM C 33	100	95 to 100	80 to 100	50 to 85	25 to 60	10 to 30	2 to 10
% Deviation	9	7	Met	Met	Met	Met	Met

Assessment. The recycling process failed to produce an aggregate meeting the ASTM C 144 or ASTM C 33 standard. The *Technical Specification for Shock-Absorbing Concrete (SACON)* requires conformance with ASTM C 144. The objective was not met because the variance from the specification exceeded 5 percent. Results from the sieving of samples taken from the blended aggregate used to produce the recycled SACON showed 9 percent of the material by weight exceeded 9.5 mm in size. The criterion was developed by WES to reduce ricochet potential. No ricochets were observed during the accelerated durability shoot at ATC. The line-of-fire was perpendicular (90°) to the barrier during this test. Additional ricochet testing should be conducted to determine if the criterion is necessary. If larger particles of SACON do not increase ricochet potential or decrease durability significantly, the recycling process could be simplified.

5.1.19 Objective 6.6. Compare physical characteristics of recycled SACON to the original.

Data. The seven-day compressive strength of polypropylene-fiber SACON made from new materials was determined to be 638 psi. The strength of polypropylene-fiber SACON made using recycled aggregate was determined to be 997 psi.

Assessment. The compressive strength of the recycled sample was 36 percent greater than that of a SACON block made from new materials. The objective to produce a block with less than a 5-percent deviation in physical properties was not met.

5.1.20 Objective 6.7. Determine the nonrecurring (capital) costs associated with recycling.

The unit operations that define the recycling operation are defined in Chapter 4, Section 4.32.4. Assuming the use of existing equipment supplemented with rented equipment, no nonrecurring costs will be incurred by an installation to conduct the storage and transportation, breaking, crushing, magnetic separation, sieving, blending, remixing, casting curing, or demolding and transportation operations which constitute the recycling process.

5.1.21 Objective 6.8. Determine the recurring costs associated with SACON recycling.

The recurring costs associated with SACON recycling have been summarized by WES. The summary was based upon recycling 1 cubic yard of SACON. The data presented in Table 5-32 are an estimate of the cost of labor and equipment for recycling 1 yd^3 (0.76 m^3) of SACON blocks.

TABLE 5-32. RECURRING COSTS ASSOCIATED WITH SACON RECYCLING

Transportation (assuming processing is done within 10 miles of the range)		
Truck rental 1 hr at $40/day and $0.40 per mile	$ 9.00	
Driver 1 hr at $18.00/hr	$ 18.00	
		$ 27.00
Size reduction Preliminary cutting and resacking		
Two unskilled laborers 3 hr at $22.55	$135.30	
Equipment costs for compressor and pneumatic Hammer 3 hr at $105/day	$39.38	
		$174.68
Crushing Two unskilled laborers 7 hr at $22.55	$315.70	
Equipment cost for vibratory roller with operator 7 hr at $330/day	$288.75	
		$604.45
Sieving and repackaging One skilled laborer 10 hrs at $29.48/hr	$294.80	
Two unskilled laborers 10 hr at $22.55	$451.00	
Cost for sieve shaker operation 10 hr at $5.50/hr	$ 55.00	
		$800.80
Maintaining safety and dust control during operation including personal protective equipment	$525.00	
		$525.00
Disposal of Residual Materials		
Assuming all residual materials (filters, protective clothing etc.) can be classed as nonregulated wastes. Protective equipment and filters estimated at 30 lb. Dust and nonrecyclable fines are estimated at 972 lb. Cost of disposing of 1002 lb at $0.08/lb plus materials	$ 80.16	
		$ 80.16
Total Cost Of Recycling	$2,212.09	
Value of recovered materials		

TABLE 5-32 (CONT'D)

Value of aggregate produced in recycling (assuming 60% of the SACON is recovered as fine aggregate) 1958 lb of sand at $0.017/lb	$ 24.78	
		$ 24.78
Net Cost Of Recycling	$2,187.31	

The cost of recovering appropriately sized aggregate from the used SACON blocks is approximately 100 times the cost of purchasing new aggregate material. The cost to dispose of 2403 pounds of SACON solid waste in bulk would be approximately $600. The cost is based upon a disposal rate of $0.08 per pound plus materials. Disposal of the used SACON as a solid waste coupled with the purchase of new aggregate material would be approximately 75 percent cheaper than recovering the aggregate material.

5.1.22 Objective 6.9. Assess personnel safety during the SACON recycling demonstration.

Data. A videotape of the recycling process was made by WES.

Assessment. A job hazard analysis (table 5-33) was made based upon the videotape of the recycling operation (ref 56). The risks assigned were based upon the potential severity of the hazard and the perceived probability of the accident. An explanation of the risk codes used is presented as Table 5-34 (ref 57).

TABLE 5-33. RECYCLING OPERATION - JOB HAZARD ANALYSIS

Job Hazard Analysis	Job Title/Operation: SACON Recycling Operation			
Basic Job Steps	Existing/Potential Hazard	Risk	Corrective Measures	Risk
1. Conduct daily safety briefing to review potential hazards.				
2. Blocks will be reduced to fragments approximately 6 inches in length, using a jackhammer.	2a. Dust problem and exposure when handling. 2b. Personnel injured when using jackhammer.	IID IID	2a. Use appropriate PPE in accordance with Industrial Hygiene guidance. 2b. Personnel will be trained in the use of a jackhammer and follow 2a.	IIE IIE
3. The fragments will be placed in fabric bags.	3. See 2a.	IID	3. Use plastic-lined (6-mil polyethylene) fabric bags and follow 2a.	IIE
4. The bags will be placed onto a concrete floor. Two wooden ramps made from 4- by 4-inch lumber will be used to elevate the roller onto the bags and the two wooden ramps will be removed after the roller is on the bag.	4. Personnel injured from roller.	IID	4. The operator will be experienced and nonessential personnel will not be near the roller.	IIE
5. The steel roller will make enough passes over the bags to reduce the used concrete to fragments smaller than 9 mm.	5a. The bag ruptured (see 2a). 5b. Steel roller hit an obstacle.	IID IID	5a. See 2a. 5b. Conduct operations in a large enough area and use a ground guide when needed.	IIE IIE
6. Bag will be emptied into sieve and steel fragments will be collected magnetically using a bar magnet located across the sieve inlet.	6. See 2a.	IID	6. See 2a and ensure proper ventilation.	IIE
7. The metal fragments will be transported by a conveyor belt to a metal pan, weighed, and disposed of.	7. See 2a.	IID	7. See 2a and material will be sampled to determine proper disposal procedures.	IIE
8. The crushed, magnetically cleaned SACON will be sieved using a vibrating sieving system.	8a. See 2a. 8b. Sieve and cyclone dust collector failed.	IID IID	8a. See 2a, ensure all hoses and bags are sealed and dust collecting cyclone is operating properly. 8b. Stop operation, identify problem, correct problem using appropriate PPE in accordance with Industrial Hygiene guidance.	IIE IIE

TABLE 5-33 (CONT'D)

Job Hazard Analysis	Job Title/Operation: SACON Recycling Operation			
Basic Job Steps	Existing/Potential Hazard	Risk	Corrective Measures	Risk
9. The sieved fractions from crushed SACON will be combined and used to make the new blocks.	9. See 2a.	IID	9. See 2a.	IIE
10. All materials not passing through the No. 4 and 100 sieves will be discarded.	10. See 2a.	IID	10. See 2a and 7.	IIE
11. The combined aggregate will be added to a cleaned commercial transit mixer.	11. See 2a.	IID	11. See 2a, ensure proper ventilation, and remove any nonessential personnel.	IIE
12. The additional components needed for the concrete will be weighed and added to the mixer.	12. See 2a.	IID	12. See 2a.	IIE
13. The fresh SACON mixture will be poured in individual block molds.	13. Personnel struck by equipment.	IID	13. Personnel will work slowly and be aware of the operation.	IIE
14. A clear silicate or latex-curing compound will be applied to the exposed concrete surface.	14. Exposure when handling.	IID	14. Use appropriate PPE in accordance with Industrial Hygiene guidance.	IIE
15. After 28 days of curing, the molds will be removed and the blocks will be inspected.	15. Strains from lifting and removing forms.	IID	15. Use adequate number of people in accordance with safety guidance.	IIE
16. All blocks will be marked with serial numbers and labeled as recycled, palletized, and transported.	16. Personnel injured from lifting.	IID	16. Use appropriate material- handling equipment.	IIE

TABLE 5-34. JHA RISK CODE DEFINITIONS

Hazard Severity		
Description	Category	Mishap Definition
Catastrophic	I	Death or system loss
Critical	II	Severe injury, severe occupational illness, or major system damage
Marginal	III	Minor injury, minor occupational illness, or minor system damage
Negligible	IV	Less than minor injury, occupational illness, or system damage
Probability of Accident		
Frequent	A	Likely to occur frequently
Probable	B	Will occur several times during life of item
Occasional	C	Likely to occur sometime in life of an item
Remote	D	Unlikely but possible to occur in life of item
Improbable	E	So unlikely, it can be assumed occurrence may not be experienced

5.1.23 Objective 6.10. Determine the adequacy of protective equipment (PPE).

Data. The industrial hygiene results from the air monitoring during the recycling process are presented in Tables 5-35 and 5-36. The exposure categories listed in Tables 5-35 and 5-36 refer to those listed on DA Form 4700. Category 1 indicates airborne levels are below permissible limits and that no work changes are necessary. Category 2 means airborne levels are close to permissible limits, necessitating additional sampling and the temporary use of respiratory protection during the operation. Category 3 indicates airborne levels are above permissible limits and the following actions should be implemented (where feasible) to prevent overexposure:

(1) Ventilation system improvements required (general and/or local exhaust).

(2) Engineering controls required.

(3) Employee work practices need improvement.

(4) Improve housekeeping.

(5) PPE mandatory until exposure is below permissible limits.

TABLE 5-35. WES RECYCLING OPERATION, INDUSTRIAL HYGIENE RESULTS

Date 1997	WES Location	Operation Description	Lead, mg/m^3 Exposure	Lead, mg/m^3 Limit	Exposure Category	WES PPE Required	WES ID No.
17 Oct	"Poorhouse"	Jackhammer	0.0095	0.05	1e	Mandatory	PZ 970096
17 Oct			.025	.05	2e		PZ970097
3 Nov	Building 6000	Sieving/separating	.025	.05	2e		PZ970121
3 Nov			.039	.05	2e		PZ970122
27 Oct	WES	Forklift operation	.044	.05	2e		PZ970117
3 Nov	Building 6000		< .015	.05	1e		PZ970127
3 Nov		Sieving/bagging	.013	.05	1e		PZ970125
31 Oct		Bagging/pouring	.038	.05	2e		PZ970113
3 Nov		Sieving/conveyor	.020	.05	2e		PZ970123
3 Nov			.038	.05	2e		PZ970124
27 Oct		Sieving/separating/ conveyor	< .037	.05	2e		PZ970115
17 Oct	Hangar 4/ Building 6000	Crushing	.004	.05	1e		PZ970096
3 Nov	Building 6000	Sieving	< .014	.05	1e		PZ970226
27 Oct		Sieving/bagging/ pouring	< .038	.05	2e		PZ970116

TABLE 5-36. WES RECYCLING OPERATION, INDUSTRIAL HYGIENE RESULTS, PARTICULATE

Date, 1997	WES Location	Operation Description	Silica Quartz, mg/m^3 Exposure	Silica Quartz, mg/m^3 Limit	Exposure Category	WES PPE Required	WES ID No.
15 Sep	Hangar 4	Crushing/pouring	<0.02	0.10	1e	Mandatory	PZ97087
8 Oct	Building 6000	Sieving/shoveling	<0.02	0.10	1e		PZ970094
15 Sep	Hangar 4	Crushing	0.04	0.10	1	No	PZ970085
15 Sep		Crushing/pouring	0.10	0.10	3e	Mandatory	PZ970086
Particulate Respirable							
15 Sep	Hangar 4	Crushing	1.00	0.10	3e	Mandatory	PZ97084
Crystalline Quartz							
15 Sep	Hangar 4	Crushing	<0.02	0.10	2e	Mandatory	PZ97084
Cristobalite							
15 Sep	Hangar 4	Crushing	<0.05	0.05	2e	Mandatory	PZ97084
Tridymite							
15 Sep	Hangar 4	Crushing	<0.10	0.05	3e	Mandatory	PZ97084

Assessment. The Health and Safety Plan developed by WES specified EPA Level C as the working uniform for SACON recycling. The PPE consisted of long-sleeved shirts and full-length pants, leather or rubber steel-toed safety boots, optional hard hat, eye protection, hearing protection as required, disposable coveralls providing full body coverage, disposable shoe coverings, and an air-purifying respirator with a TC 21C-155 filter for airborne lead. After reviewing the air-monitoring data, the WES Industrial Hygienist recommended continuing with this level of PPE until exposure is shown to be below permissible limits. It is important to note that the recycling activity was conducted using a substantial number of unused blocks. Thus, the airborne lead levels were not worst case.

5.2 Technology Comparisons

SACON, when used in a backstop-type application, compares directly with commercial off-the-shelf (COTS) bullet traps. The function of these COTS bullet traps is to stop the bullet and contain the bullet debris within the trap. The use of SACON, as well as COTS bullet traps, is also comparable to the use of soil berms on ranges. Soil berms are designed to stop the flight of the bullet. A berm's ability to control metal dispersion and contain the metals varies with soil type and berm shape. Depending on lead mobility and regulatory constraints which may be placed on range operations, periodic cleanup of metals deposited in the soil berms may be required.

5.2.1 COTS Bullet Trap Performance Characteristics

There are a number of different types of bullet traps available on the market. The bullet traps differ in the manner in which they reduce the kinetic energy of the bullet to stop its flight. Generally, bullet traps will accomplish this through three basic designs:

- Impact. An impact-type trap will typically employ an armor plate to stop the flight of the bullet on impact. This trap is designed to stop the flight in a manner that does not result in ricochets or backsplatter back to the firing line. Control and containment of the metal debris is not a design factor.

- Deceleration. A deceleration-type trap deflects the bullet into an enclosed chamber where it spins or impacts onto a series of plates until the energy of the round is dissipated. Once the energy is expended, the bullet comes to rest in a containment bucket, where it can be retrieved and recycled.

- Friction. A friction-type trap directly imparts friction on the bullet to stop the flight of the bullet within the trap material. The bullet debris is retained within the trap material. A SACON backstop is a friction-type trap. COTS friction traps typically use various configurations of rubber as the bullet-stopping media, some of which facilitate the separation of bullet fragments from the friction media.

In order to assess the potential benefits of COTS bullet traps for range operations, AEC initiated a test program concurrently with the SACON test program. Three of the most popular COTS bullet traps were selected by AEC and tested by ATC as part of TECOM Project No. 1-CO-160-000-192. The traps selected for testing represented the friction and deceleration categories. Impact-type traps were not tested due to their inability to contain bullet debris. Testing of the COTS bullet traps was conducted to determine the bullet containment efficiency, number of bullets fired before a major maintenance activity, airborne lead concentrations, and waste characteristics. These test parameters can be directly compared to the test data developed for the 25-Meter Range SACON application. Testing was conducted by firing three- to eight-round bursts of M855 ammunition from a loosely mounted SAW from a distance of 25 meters. The bullet impacts were concentrated within approximately a 12-inch diameter circle to simulate the concentration pattern observed on 25-Meter Zero Ranges. The performance characteristics of each type of trap are as follows:

5.2.1.1 Steel Deceleration Trap (SDT)

The SDT has steel plates on the top and bottom set at an angle from horizontal to deflect bullets into a deceleration chamber. When bullets enter the trap, they strike a series of angled impact plates oriented in a circular shape that directs them into a collection drum. The tested trap had a dust collection unit (DCU), which consisted of a blower unit, a filter unit, and a collection drum. The DCU required three-phase, 240-volt, 208-amperage electrical power for operation.

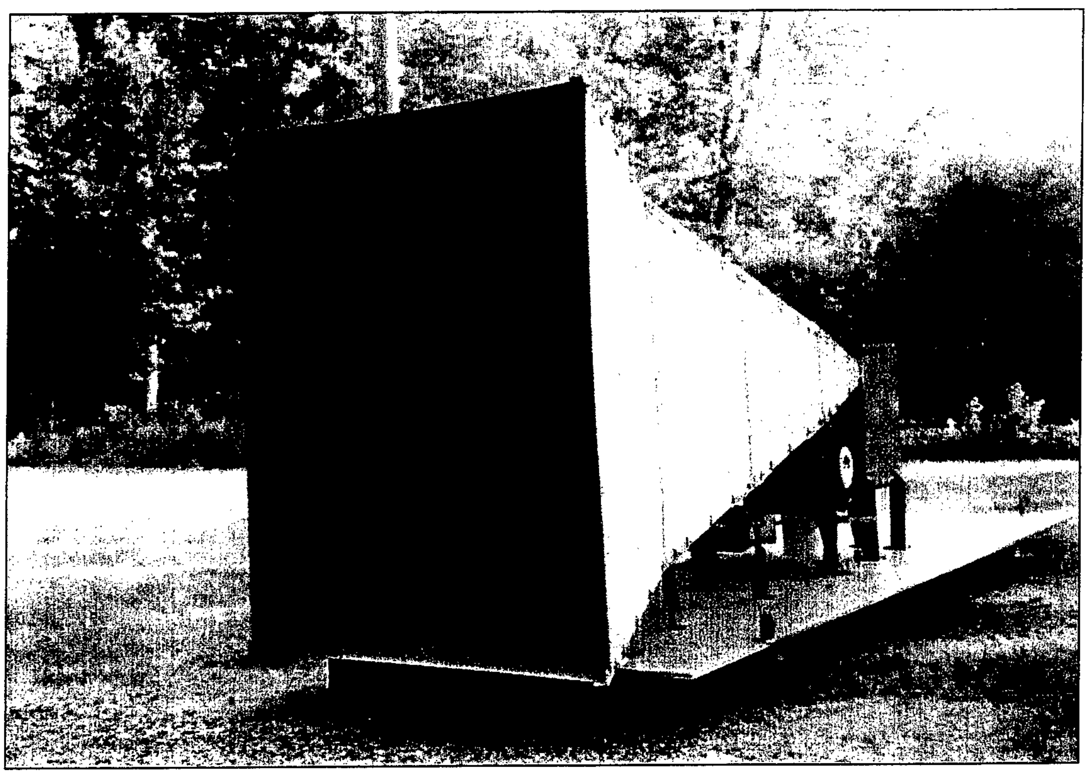


Figure 5-40. Steel deceleration trap.

Performance: Testing was limited to firing 5000 rounds and focused upon quantifying dust emissions from the trap. Dust and backsplatter concerns had previously been documented in a Navy (Rodrigues) test report and observed at Tyndall Air Force Base (AFB) and Hurlburt Airfield. The SDT was found to be capable of containing 83.7 percent of the bullet debris fired into the trap. Excluding the mass of material removed from the front deflector plates, the containment efficiency of the trap decreases to 79.9 percent. This containment efficiency was achieved by firing immediately in front of the deceleration chamber opening, which would allow for optimum containment efficiency.

During use, a dust cloud developed at the trap entrance. Evidence of rounds breaking into fragments was observed in the trap collection bucket (fig. 5-41). Use of the trap with a success-oriented bullet entrance pathway resulted in the noncontainment of approximately 20 percent of the bullet debris. With a relative lack of fragments observed outside the trap, principal losses appear to have been through aerial transport of dust. The trap was examined by ATC/AEC to determine potential causes for the poor dust removal performance. A design flaw in the filter housing of the DCU appears to have resulted in the filter gasket not being able to be compressed adequately. As a result, lead dust was probably pulled through this joint during DCU operation, contributing to the poor performance of containment efficiency and to the elevated airborne dust emissions. The DCU problem would not have affected the lead dust releases measured at the side and in front of the trap.

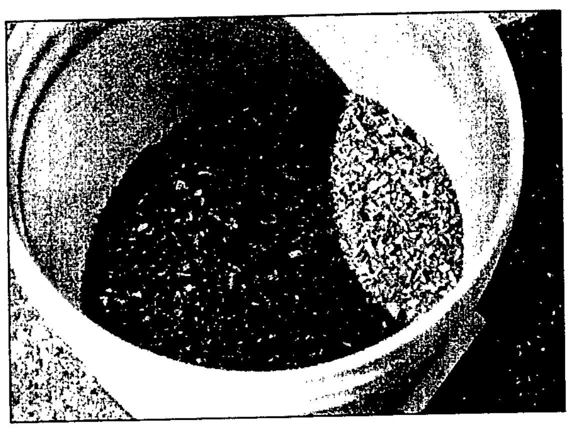


Figure 5-41. Bullet fragments collected by the deceleration trap.

Lead levels were measured at the DCU exhaust port, at the sides of the trap entrance, 12.5 meters in front of the firing line, and at the firing line. The results are presented in Table 5-37.

TABLE 5-37. AIRBORNE LEAD CONCENTRATION - DECELERATION TRAP TESTING

SDT - Air Samples for Lead (Firing Operation)			
Monitor Location	8-Hour TWA, mg/m^3	Action Level Exceeded?	Sampling Period, min
Firing position	0.019	No	299
Right side of trap	1.45	Yes	355
Left side of trap	0.198	Yes	84
Midrange	0.0095	No	350
DCU exhaust port	4.76	Yes	359
Data collector	0.003	No	263

The lead action level of 0.03 mg/m^3 and the permissible exposure limit of 0.05 mg/m^3 defined in 29 CFR 1910.1025 were exceeded at the left side, the right side, and the exhaust port of the trap. Because the trap was not containing the lead, it can be concluded that the lead levels in the soil surrounding the trap would increase over time.

The bullet debris gathered in the collection buckets yielded a scrap metal which may have a recycle value. Maintenance activities on the trap, which may include replacement of deflector plates, replacement of deceleration chamber components, DCU filter replacement, etc., result in lead-contaminated components that require proper handling and disposal. The spent filters and materials used to remove dust from the trap surfaces will require disposal as a hazardous waste. The metal components of the trap may have a salvage value if a market exists for the scrap metal. If the metal does not have value, then it will likely have to be disposed of as a hazardous waste.

5.2.1.2 Granular Rubber Friction Trap (GRFT)

The GRFT (fig. 5-42) has a sloped front surface with a rubber cover, a galvanized steel bedplate, and a support frame. The space between the cover and bedplate contains rubber granules. The rubber cover allows bullets to penetrate and be captured by the rubber granules with little or no fragmentation or backsplatter. The tested trap had three access doors beneath the trap for removal and separation of rubber granules and spent bullets.

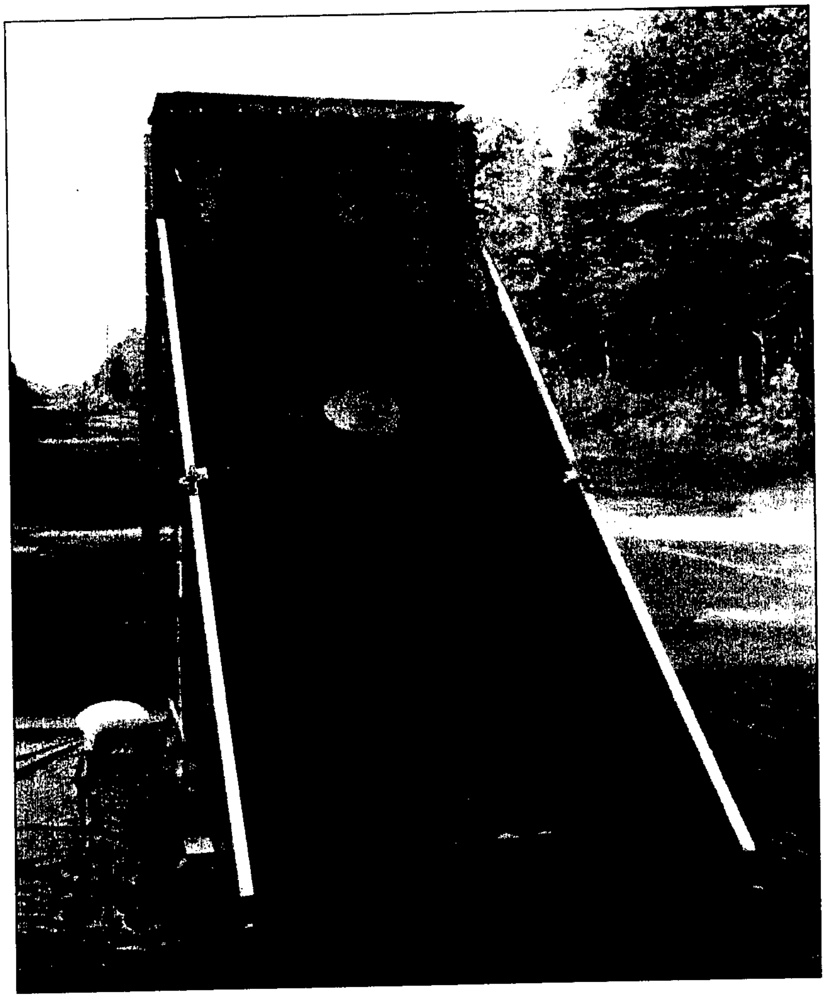


Figure 5-42. Granular rubber friction trap.

Performance: Testing was conducted in a fashion similar to that of the deceleration trap. The GRFT was fired upon from a distance of 25 meters using a SAW. Initial testing of the GRFT resulted in the trap catching on fire after 6000 rounds of ammunition were fired into it. No tracer rounds were used during the test. A total of 3200 rounds were shot into the trap in approximately 1.5 hours before a maintenance action was required. A patch was applied as shown in Figure 5-43.

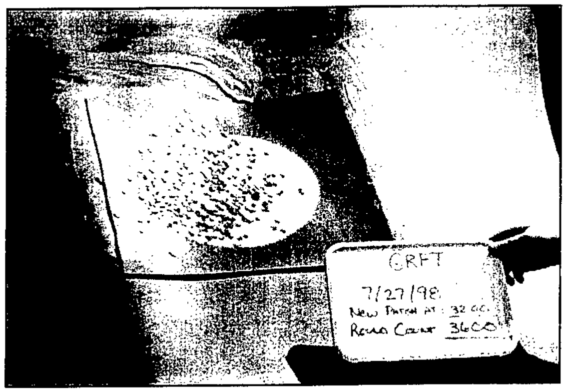


Figure 5-43. GRFT patch.

Approximately 1.75 hours after the patch was applied, firing resumed. The GRFT received an additional 2800 rounds before the trap was destroyed by fire (fig. 5-44). The fire occurred 1.3 hours after patching the rubber cover. The rubber adhesive used was highly flammable (as are most rubber adhesives). The trap manufacturer's analysis of the cause of the fire is that the off-gassing of the glue created a flammable condition in the void space between the granules. The off-gassing most likely reduced the temperature required to ignite the trap. The energy dissipation created by the friction action of the trap caused a buildup of heat. Although temperature measurements were not made during this test, rubber temperatures in the interior of shredded rubber traps have been reported to reach as high as 1500 °F (ref 28). A granular rubber sample was analyzed for flash point. The flash point of the granular rubber was measured to be 1305 °F.

Figure 5-44. GRFT fire.

In order to generate data destroyed by the fire, a smaller-scale second test was conducted to determine the ability of the trap to contain lead and to reclaim bullet debris from the granular rubber, and to establish the waste characteristics of the rubber after bullet debris removal. A wooden box was used to house the granular rubber (fig. 5-45). A total of 2000 rounds were fired into the box in 4 hours. Temperature measurements were taken from within the box every 100 to 200 rounds. The maximum temperature measured was 207 °F.

Figure 5-45. Granular rubber test fixture.

Data from these sampling events are presented in Tables 5-38 and 5-39.

TABLE 5-38. SECOND TEST TRAP TOTAL RCRA METALS AND ZINC

Sample Location	Pb, mg/kg	Ag, mg/kg	As, mg/kg	Ba, mg/kg	Cd, mg/kg	Cr, mg/kg	Se, mg/kg	Zn, mg/kg
Background	16.4	<20	74.40	3.20	0.40	13.00	3.60	7.8
Before recycle	5082.06	<20	93.4	<100	<5	<20	<100	-
After recycle	192.77	<20	46.00	2.40	0.40	20.40	22.20	-

TABLE 5-39. SECOND TEST TRAP TCLP DATA

Sample Location	Pb, mg/L	Ag, mg/L	As, mg/L	Ba, mg/L	Cd, mg/L	Cr, mg/L	Se, mg/L
Background	<0.12	0.10	<0.10	0.57	<0.025	<0.10	<0.50
Before recycle	264.4	<0.10	<0.10	<0.50	<0.025	<0.10	<0.50
After recycle	40.53	<0.10	<0.10	<0.50	<0.025	<0.10	<0.50

An accurate mass balance could not be conducted with this type of trap because the bullet debris is mixed in the granular rubber media. In order to assess containment efficiency, the trap was monitored for dust emissions and provisions were made to collect any debris that fell out of the trap during test firing. There were no significant dust emissions during the test evolution. Also, no backsplatter was observed during the testing nor were any bullet fragments found outside of the trap. Based on air monitoring data and visual observations, the trap is assumed to have contained nearly 100 percent of the rounds fired into it.

The ability of the lead which had been captured by the trap to leach into the environment could not be directly monitored during this test due to funding restraints; however, a subjective assessment of the potential for movement of solubilized lead can be made based on the TCLP analysis of the granular rubber medium. Background samples were taken from the trap prior to the live fire testing and analyzed for total metals and TCLP. Samples were also collected prior to and after a recycling event to characterize the trap material.

The TCLP data show that the lead in the trap before and after recycling has the potential to be mobilized in a soluble form. Whether or not the rubber cover on the trap will prevent the mobilization of the lead in the trap cannot be assessed; however, traps of design similar to the one tested here are marketed that do not provide a barrier between the lead-contaminated granular rubber medium and storm water. These traps with no weather protection provide a significant risk for lead leaching out of the trap and into the environment.

The original intent of this test was to shoot the trap to its first major maintenance point, which the manufacturer had estimated to be approximately 50,000 to 70,000 rounds, using the M855 round. The testing was abbreviated due to the fire during the first live fire test. The lead containment results tend to agree with the results presented by the Navy (Rodrigues) test report. However, the Navy report did not assess the potential for soluble lead migration from the trap. (Note: The Navy testing was conducted on an indoor range and the primary objective was to assess the trap for an indoor application. Lead leaching was not an assessment issue.) Before this trap is applied on an outdoor range, the lead-leaching potential should be further investigated. Also, effects of weathering on the trap should be considered (i.e., will the trap freeze and become a ricochet hazard, will photodegradation affect performance, etc.). The issue with the trap catching on fire also requires further investigation There was significant heat buildup resulting from the friction of rubber stopping the bullet. Whether limitations need to be placed on the use of automated fire on the trap warrants further investigation.

The first major maintenance event predicted by the manufacturer was a metals recovery event required after 50,000 to 70,000 rounds had been fired from a single firing point. The manufacturer's field representative indicated the need to remove bullet debris was structural in nature because of the additional mass created by the captured bullets. The recovery operation consists of using a vacuum to segregate the collected bullets from the granular rubber. The granular rubber is then returned to the trap for reuse while the bullet fragments are removed as scrap metal. This maintenance event was conducted after 2000 rounds had been fired into the trap. A 79.5-percent removal efficiency was achieved by the maintenance event. Assuming 80 percent to be a typical removal efficiency, then 20 percent of the bullet debris (which will probably be primarily lead) will remain in the trap after each maintenance event.

The samples taken before attempting to clean the trap from the live fire test contained an enormous amount of lead and the TCLP for lead was above the RCRA limit of 5 mg/L. After recovery, the total concentration of lead decreased; however, the leachable lead remaining still exceeded the RCRA limit. The metals that are separated can be handled as a recyclable material; however, should the need to dispose of the trap material be necessary in the future, then this material will be handled and disposed of as a hazardous waste.

5.2.1.3 Composite Rubber Block Friction Trap (CRBFT)

The modular rubber blocks used were created by combining recycled tire rubber and a Kevlar-reinforced bonding agent under extreme pressure (ref 27). Each block was 9 inches high, 24 inches wide, and 13.5 inches deep and weighed approximately 89.5 pounds. The tested trap was 4 feet high by 4 feet wide and contained two columns with each column containing five blocks (fig. 5-46). A rubber-coated 3/8-inch steel backplate and compression system was provided to secure the blocks.

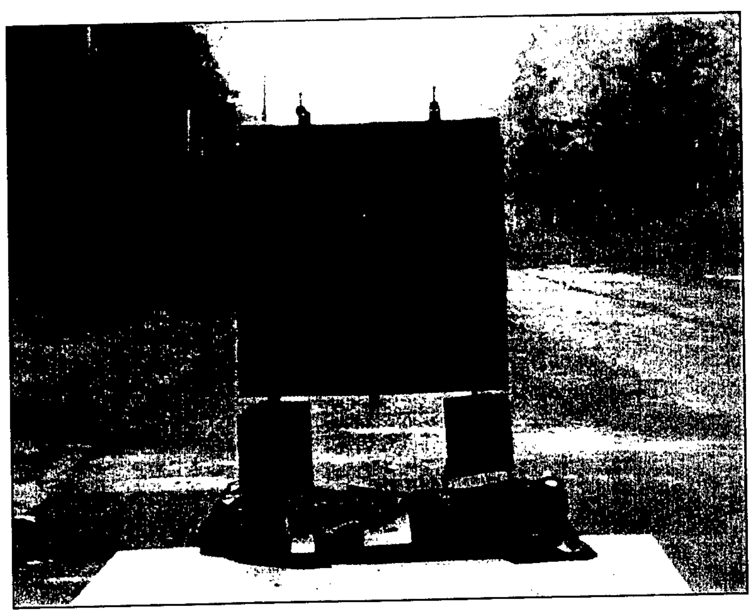


Figure 5-46. Rubber block friction trap.

Performance: The intent of this test was to shoot the trap to its first major maintenance event and determine the technology's bullet containment efficiency. The first major maintenance action for the rubber block trap was defined as a block rotation. The manufacturer's criterion to require a block rotation was a 4-inch penetration of rounds over the surface area of a 5-inch diameter circle or if cracks over 2 inches appeared. The rubber block trap met the depth-of-penetration criterion and required a block rotation action after 1800 rounds. During this first trial, test personnel noticed a burning rubber smell after approximately 700 rounds. Puffs of black smoke were emanating from the impact cavity after 1800 rounds and the material appeared to have melted. A second trial was conducted that day. No tracer rounds were used during either trial.

During the second trial, depth-of-penetration measurements were taken after every 200 rounds. After 800 rounds had been fired, the black smoke originating from the firing cavity reached the firing position. The depth-of-penetration criterion necessitated a block rotation after 1900 rounds (fig. 5-47).

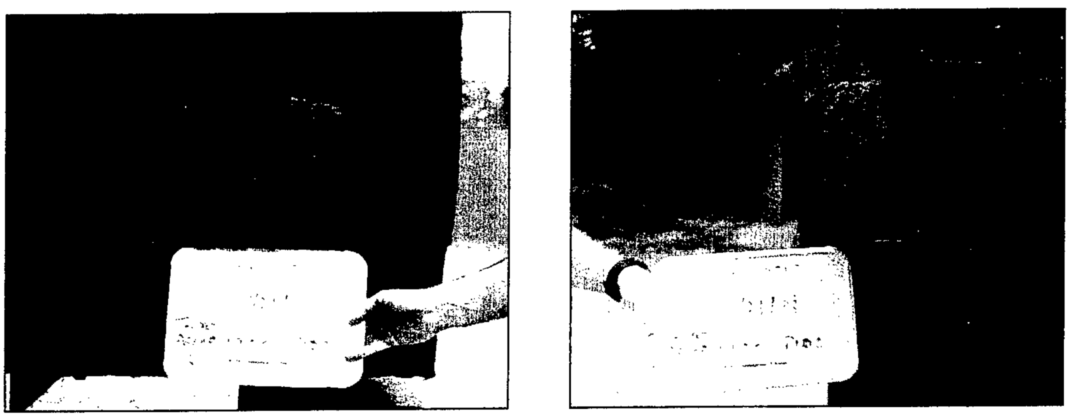


Figure 5-47. Accelerated durability after 1900 rounds (front and side views).

The block rotation was not conducted and firing was continued to determine the number of rounds required to penetrate through the blocks. Figure 5-48 shows a side view of the trap after 3100 rounds were fired in the second trial.

Figure 5-48. Side view - 3100 rounds fired.

A total of 3200 M855 rounds were fired during the second trial before the end of the day. The trap smelled of burning rubber throughout the second trial.

The trap switched from a smoldering to a fully engulfed fire and was consumed approximately 15 hours after firing was terminated for the day (fig. 5-49). The energy dissipation created by friction caused a buildup of heat, which was believed to have been the cause of the fire. Temperature measurements were not taken during the test. The flash point of the rubber block material was determined by laboratory testing to be 1425 °F.

Figure 5-49. Rubber block trap fire (trap tipped on side).

Like the SACON blocks and the granular rubber trap, an accurate mass balance could not be conducted with this type of trap because the bullet debris was mixed in the rubber media. In order to assess containment efficiency, the trap was monitored for dust emissions and provisions were made to collect any debris that fell out of the trap during test firing. There were no significant lead dust emissions during the test evolution. Also, no backsplatter was observed during the testing nor were any bullet fragments found outside of the trap. Analysis of the small amount of rubber debris that fell out of the trap resulted in the determination that the trap maintained a containment efficiency of 99.99 percent. Based on the air monitoring data, debris analytical data, and visual observations, the trap is assumed to have contained nearly 100 percent of the rounds fired into it.

The ability of the lead captured within the trap to leach into the environment could not be directly monitored during this test due to funding restraints; however, a subjective assessment of the potential for movement of solubilized lead can be made based on the TCLP analysis of the rubber medium. Background samples were taken from the trap prior to live fire testing and analyzed for total metals and TCLP. Samples were collected after the firing tests to characterize the trap material. Data from these sampling events are presented in Tables 5-40 and 5-41.

TABLE 5-40. TOTAL RCRA METALS

Sample Location	Pb, mg/kg	Ag, mg/kg	As, mg/kg	Ba, mg/kg	Cd, Mg/kg	Cr, mg/kg	Se, mg/kg
Background	<24	<20	88.60	<100	<5	40.00	<100
Debris pile	1604.00	<20	76.59	<100	<5	<20	<100
First impact area	3543.27	<20	69.20	<100	<5	<20	<100
Second impact area	682.42	<20	19.00	<100	<5	<20	<100

TABLE 5-41. TCLP DATA

Sample Location	Pb, mg/L	Ag, mg/L	As, mg/L	Ba, Mg/L	Cd, mg/L	Cr, mg/L	Se, mg/L
Background	5.5	<0.10	0.49	<0.50	<0.025	<0.10	<0.50
Debris pile	112.50	<0.10	0.53	<0.50	<0.025	<0.10	<0.50
First impact area	79.65	<0.10	<0.05	<0.50	<0.025	<0.10	<0.50
Second impact area	126.20	<0.10	<0.05	<0.50	<0.025	<0.10	<0.50

The TCLP data show that prior to test firing the lead in the trap failed to meet the RCRA TCLP requirement of 5.0 mg/L. It is not known whether the test blocks may have been exposed to lead contaminants prior to receipt at ATC or if the components used to make the rubber blocks contained lead. After test firing, the debris pile and the impact area samples contained significant levels of leachable lead. These data indicate that there is a potential for lead to leach into the environment from this type of trap if used on an outdoor range.

Before this trap is applied on an outdoor range, lead leaching potential should be further investigated. Also, effects of weathering on the trap should be considered (i.e., will the trap freeze and become a ricochet hazard, will photodegradation affect performance, etc.). The issue with the trap catching on fire also requires further investigation. There is significant heat buildup resulting from the friction of the rubber stopping the bullet. Whether limitations need to be placed on the use of automated fire on the trap requires further investigation by the manufacturers.

The samples after the live fire test contained a significant amount of lead, and the TCLP for lead was above the RCRA limit of 5 mg/L. The metals that are separated can be handled as a recyclable material; however, should the need to dispose of the trap material be necessary in the future, then this material will be handled and disposed of as a hazardous waste.

5.2.2 Conventional Soil Berm

Typically, a small arms range will employ the use of a soil berm when stopping the fired rounds is necessary (fig. 5-50). A berm's ability to contain the bullet debris and control metal dispersion varies with soil type and berm shape as well as other site-specific characteristics such as soil pH, soil chemistry, extent of vegetative cover, and local climatic conditions. Depending on lead mobility and regulatory constraints which may be placed on range operations, periodic cleanup of metals deposited in the soil berms may be required.

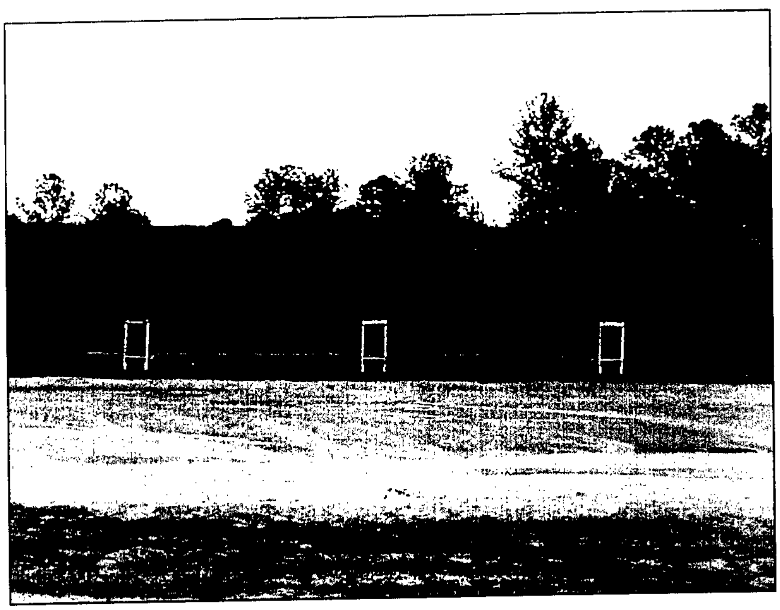


Figure 5-50. Soil berm bullet trap.

A soil berm is in essence a friction type of bullet trap. The soil is the medium that imparts friction on the bullet to terminate its flight. The berm is designed to stop the flight in a manner that does not result in ricochets or backsplatter back to the firing line. Control and containment of the metal debris have not typically been a factor in berm designs. The design and construction of soil berms is governed by several factors: ammunition used on the range, SDZ limitations, range location with respect to other ranges, available impact area, type of training being conducted on the range, etc. As a result of these varying parameters, a large variety of berm heights and slopes are found on military ranges.

Performance: For comparison purposes only, the performance characteristics of a berm used on a 25 meter zero range will be described here. Typically, the M855 ammunition used in zeroing the M-16 rifle breaks up on impact with the berm. The soil berms, which often experience significant soil erosion problems, will not contain the bullet debris within the berm. Aerial dispersion of soil and bullet debris from the impact point on the berm has been observed. This debris has been found deposited as far as 100 meters behind the berm. Also, the bullet debris and soil remaining in the bullet pocket (the incised area on the berm face where the majority of the rounds impact) is highly susceptible to transport off range by storm water runoff.

In addition to transport of bullet debris resulting from firing, transport via leaching of soluble lead is possible. TCLP analyses from berms on numerous ranges across the country have failed the 5-mg/L RCRA limit. The potential for leaching of this solubilized lead to groundwater is dependent upon site-specific characteristics and must be evaluated on a case-by-case basis.

Maintenance of soil berms currently consists of filling in bullet pockets and repairing damage caused by storm water erosion on a periodic basis. The frequency of this maintenance varies with the soil type, berm slope, local climatic conditions, and volume of rounds fired on the range. For example, a range at Fort Jackson that receives an annual throughput of approximately 30,000 rounds per lane per year may require semiannual maintenance to fill in bullet pockets in addition to major berm and storm water runoff channel contouring once every three years.

The TCLP waste characteristic that the berm soil exhibits necessitates the handling and disposal of the soil as a hazardous waste upon its removal from the range. Currently, cleanup activities are required only when a range is closed. If the mobility of the lead presents an environmental threat, then more frequent maintenance and cleanup activities may be required to maintain the range in an operational status.

5.2.3 Performance Comparisons

Comparison of SACON to COTS bullet traps and soil berms is based on the following performance characteristics:

- Bullet debris containment.
- Airborne lead concentrations and impacts.

- Maintenance frequency and requirements.

- Waste characteristics and disposal requirements.

Bullet Debris Containment: The bullet debris containment efficiency of the technologies is presented in Table 5-42. The containment efficiency numbers presented here account for only the bullets and bullet fragment debris contained within the trap. The SACON data do not reflect the fact that SACON and bullet debris that fell out of the impact cavity in the backstop was confined to a small pile immediately in front of the backstop. This pile was not thought to present a metals mobility problem unless disturbed by some mechanical means (e.g., lawnmowers). Based on the available data, the two rubber friction traps would appear to provide a better containment efficiency; however, neither of the rubber traps provides a containment medium that inhibits the leaching potential of the lead. All samples collected from the SACON field demonstrations at Fort Knox and USMA indicate that there is no threat of lead leaching from the backstops (or the debris pile in front of the backstops). Samples collected from the rubber friction traps indicate that this leaching potential exists with the granular rubber and rubber block traps. In general, the soil berm as presently designed is not inherently capable of containing the particulate metals or of inhibiting the lead leaching.

TABLE 5-42. CONTAINMENT COMPARISON DATA

Technology	Containment Efficiency, %
SACON	86.5
Steel Decelerator Trap	79.9
Granular Rubber Friction Trap	100
Composite Rubber Block Friction Trap	100
Soil Berm	Varies with site conditions

Airborne Lead Concentrations: Airborne emissions of lead dust from the technologies during firing operations and during maintenance provide an insight into each technology's ability to contain the hazardous metals and the potential health impact on range personnel. Table 5-43 presents representative air-monitoring data for each technology during these operations.

TABLE 5-43. AIRBORNE LEAD CONCENTRATIONS

Technology	Airborne Levels (Firing Operation), mg/m^3	Airborne Levels (Maintenance), mg/m^3
SACON	<0.002 to 0.057	<0.014 to 0.510
Steel decelerator trap	[a]0.198 to 4.76	0.014 to 0.95
Granular rubber friction trap	<0.002	Unknown[b]
Composite rubber block friction trap	<0.002	Unknown[c]
Soil berm	Unknown	Unknown[d]

[a]Dust control unit was not functioning properly during testing.
[b]Monitoring not performed during maintenance event.
[c]Maintenance event not performed due to trap fire.
[d]Monitoring and dust control measures generally are required during major earth movement operations.

SACON and the steel decelerator trap yielded elevated airborne lead levels during the firing operations at the trap. The dust generation observed during the SACON firing operations can be attributed to the accelerated rate-of-fire used during the test. A small cloud of dust developed within the SACON backstop cavity created by the bullet impacts. During field testing at Fort Knox and USMA, only occasional wisps of dust were observed during use on the ranges. This would indicate that aerial transport of lead contaminants may be possible if high rates of automated fire are used on SACON backstops.

The steel decelerator trap yielded airborne levels 1 to 3 orders of magnitude higher than either SACON or the rubber traps. The dust level at the DCU exhaust would likely have been reduced with a properly fitted filter installed in the unit. A dust cloud occurred during the accelerated rate-of-fire used during testing at ATC and has been observed by Air Force personnel during normal training operations at Tyndall AFB and Hurlburt Airfield (ref 26). Based upon observations, dust depositions in the mouth of the test trap, and the fragmentation of rounds, significant aerial transport of lead may be expected from this technology during normal training use.

Both traps representing rubber friction technology provided excellent lead dust containment during limited live fire testing conducted at ATC. No data have been collected on the levels of airborne lead emanating from soil berms during use; however, bullet fragment dispersion has been observed at significant distances behind the berms, indicating that aerial transport of metal contaminants is significant.

Airborne levels measured during SACON maintenance events warrant use of PPE and/or implementation of dust control measures. Airborne data for the rubber traps were not collected; however, lead dust can be expected to be generated within these traps as a result of bullet-on-bullet impacts. Airborne exposure levels during maintenance events that result in disturbance of the bullet trap media, regardless of whether the medium is SACON, soil, or rubber, require appropriate levels of PPE to be worn. As observed during the steel decelerator trap maintenance event, significant lead dust levels were generated, thus requiring PPE to be worn.

Maintenance: Maintenance frequency and requirements vary with bullet trap type as well as specific range application. For comparison purposes only, the various bullet-trapping technologies' performance as applied to a 25-meter range will be used here. The volume of rounds fired on one firing point is assumed to be 30,000 rounds per year of M855 ammunition. This type of known distance, fixed target range application provides the best measurable comparative platform for the use of the competing technologies. A summary of expected maintenance frequency, PPE, and waste handling requirements is provided in Table 5-44.

TABLE 5-44. PERIODIC MAINTENANCE FREQUENCY AND REQUIREMENTS

Technology	Major Maintenance Frequency	PPE Required (yes/no)	Waste Handling Requirements		
			Recyclable Material	Solid Waste	Hazardous Waste
SACON	Quarterly	Yes	SACON and bullet debris	SACON and bullet debris	None
SDT	Undetermined	Yes	Bullet debris and worn plates	None	HEPA filters
GRFT	Biennially[a]	Yes	Bullet debris	None	Rubber cover
CRBFT	10 times per year	Yes[b]	Possible[c]	None	Rubber blocks containing bullet debris
Soil Berm	Annually	Yes	None[d]	None[d]	None[d]

[a]Based upon manufacturer's estimate.
[b]Maintenance event not performed due to trap fire. No data are available on potential exposure; however, precautions should be taken until proven otherwise.
[c]Possibly dependent upon lead content of the block and the recycler's ability to separate the bullet debris from the block.
[d]No waste generated during periodic maintenance.

SACON maintenance consists of periodically removing shot-up blocks and replacing them with new blocks. With the assumed volume of 30,000 rounds per year, this maintenance would have to be performed 4 times per year. The block design used during the field demonstrations required a partial disassembly of the SACON barrier to conduct the repairs. The bullet and SACON debris that is collected during the maintenance event can either be recycled or disposed of as a solid waste. PPE is required for personnel performing the maintenance.

Steel decelerator trap maintenance consists of periodically ensuring proper DCU operation, cleaning bullet debris from the front deflector plates, collecting bullet debris from the deceleration chamber collection buckets, replacing HEPA filters in the DCU, and replacing worn or damaged deflector plates. Operational checks should be performed prior to each use. Deflector plate cleaning should be conducted on a weekly basis. The bullet debris and damaged plates that are collected during the maintenance event would likely have a limited value as scrap metal. The spent HEPA filters require disposal as a hazardous waste. PPE is required for personnel performing the maintenance.

Granular rubber friction trap maintenance consists of using a vacuum to segregate the collected lead from the granular rubber. The granular rubber is then returned to the trap for reuse while the bullet fragments are removed as scrap metal. This maintenance event would be conducted once every two years. Interim maintenance consists of patching the rubber cover ten times per year and replacing the rubber cover annually. The bullet debris that is collected during the metals recovery operation would likely have value as scrap metal. The rubber cover would likely require disposal as a hazardous waste. PPE is required for personnel performing the rubber cover replacement and the metals recovery operation.

Like SACON, the composite rubber block friction trap maintenance consists of periodically removing shot-up blocks and replacing them with new blocks. With the assumed volume of 30,000 rounds per year, this maintenance would have to be performed ten times per year. A partial disassembly of the rubber block barrier is required to conduct the repairs. The bullet and rubber block debris that is collected during the maintenance event must be handled and disposed of as a hazardous waste. Recycling to recover the bullet debris metals may be possible, depending upon the lead content of the rubber block, and the recycler's ability to remove the metals from the blocks. PPE is required for personnel performing the maintenance.

Maintenance of soil berms currently consists of filling in bullet pockets and repairing damage caused by storm water erosion on a periodic basis. With the assumed volume of 30,000 rounds per year, maintenance may include semiannual maintenance to fill in bullet pockets and major recontouring of the berm and storm water runoff channel once every three years. PPE and/or dust control measures are required for personnel performing the maintenance.

Waste characteristics and disposal requirements: The handling requirements for waste generated during maintenance of the technologies is summarized in Table 5-44. Complete disposal of the various bullet trapping technologies may be required as a result of trap failure or range closure. The waste handling and disposal requirements for each technology are summarized in Table 5-45.

TABLE 5-45. DISPOSAL REQUIREMENTS

Technology	Waste Handling Requirements		
	Recyclable Material	Solid Waste	Hazardous Waste
SACON	SACON and bullet debris	SACON and bullet debris	None
SDT	Bullet debris, worn plates, deceleration chamber, and DCU	None	HEPA filters and contaminated soil
GRFT	Bullet debris, trap structural members, and bedplate	None	Rubber cover and granular rubber
CRBFT	Possible[a]	None	Rubber blocks containing bullet debris
Soil Berm	Separated metal fraction	None	Contaminated soil fraction

[a]Possibly dependent upon lead content of the block and the recycler's ability to separate the bullet debris from the block.

The entire SACON backstop may be either recycled or disposed of as a solid waste. There were no waste materials generated during testing at USMA or Fort Knox that exhibited hazardous waste characteristics. Proper maintenance coupled with reduced leachability created by use of SACON should result in reduced soil cleanup costs in the future.

The steel decelerator trap can be recycled for the most part as scrap metal. Because of this trap's inability to contain the lead within the trap, soil remediation in the vicinity of the trap will also be required. The contaminated soil will have to be handled as a hazardous waste if removed from the range.

The granular rubber and rubber block traps both require handling of rubber materials as a hazardous waste. TCLP analysis of the rubber material after use indicates an abundant source of leachable lead is contained within the traps. With inadequate protection from storm water intrusion, lead may leach from the traps, creating future remediation requirements.

In the event of range closure, the soil in and around the berm that exhibits the TCLP waste characteristic will require handling and disposal as a hazardous waste. If the mobility of the lead presents an environmental threat, then more frequent maintenance and cleanup activities may be required to maintain the range in an operational status. These maintenance events may result in soil fractions that will require disposal as a hazardous waste.

6. Cost Assessment

The purpose of this chapter is to provide an assessment of expected operational costs for the SACON technology. To accomplish this goal, operational costs for a 200-foot wide, outdoor, 20-lane, 25-meter range were extrapolated from the demonstration data using guidance provided by the Environmental Cost Analysis Methodology (ECAM) Handbook (ref 59). To determine a range of applicability for the SACON technology from an economics perspective, an operational scenario with varied throughputs was selected for the purpose of technology comparison. The operational scenario consisted of standard outdoor 25-meter range training operations with high (30,000 rounds per firing lane), moderate (15,000 rounds per firing lane), or low (7,500 rounds per firing lane) annual throughput. Heavy metals transport risk was also factored into the economics comparison. An assumption was made that with the implementation of the Range Rule, the time period between range soil remediation efforts is proportional to the time period resulting in off-range migration of metals. The remediation frequency required to comply with the Range Rule will directly impact range operational costs. To factor remediation frequency into the cost comparisons, low-, moderate-, and high-risk scenarios were assumed. Basically, high risk equated to a required remediation effort in 5-year increments, moderate in 15-year increments, and low in 50-year increments.

To develop comparisons among the existing soil berm technology, available COTS technologies, and the SACON technology, both direct and indirect process cost data were developed for each technology. A direct cost is an accounting term for costs that are clearly and exclusively associated with a product or service (ref 59). Correspondingly, indirect process costs are those not exclusively associated with the process or service. The origin of the data used to develop both direct and indirect process cost data was primarily from this demonstration, a related COTS bullet-trap technology demonstration conducted by ATC, engineering judgments, and interviews with Range Managers. To add consistency to the comparison, technology process costs were based upon technology implementation at ATC. In doing such, Range and Environmental Protection Specialist labor was assigned a \$30 and \$45 per hour cost, respectively. Waste disposal estimates were based upon disposal through an existing contract at APG.

6.1 Cost Performance

Operational costs associated with the SACON technology were derived in detail in the cost sections of chapter 5.

High Range Usage. Table 6-1 provides expected operational costs (without recycling) for full-scale use of the SACON technology based upon an outdoor 25-meter range application with 20 lanes, each lane receiving 30,000 rounds annually. Following Table 6-1, the derivations of table entries are summarized.

TABLE 6-1. SACON COSTS - 25-METER RANGE, 20 LANES, EACH RECEIVING 30,000 ROUNDS PER YEAR

Direct Process Cost				Annual Environmental Activity Cost		Other Costs	
Start-Up		Annual Operation and Maintenance					
Activity	$	Activity	$	Activity	$	Activity	$
Equipment purchase (60 yd^3 SACON)	17,820	Labor to maintain	39,150	Solid waste management	360	Final disposal	17,664
Equipment integration/site evaluation	3,440	Miscellaneous overhead (ordering supplies, etc.)	1,000			Productivity/cycle time	Unchanged
Site preparation: 5-day skid loader rental; gravel; 3 laborers, 40 hr at $30/hr	4,871	Utilities	NA	Environmental management plan development and maintenance, Environmental Protection Specialist, 24 hr at $45/hr	1,080	Worker injury claims and health costs	NI
Installation: 2.5 hours x 4 laborers x $30/hr x 20 lanes	6,000	Operator refresher training (4 persons x 2 hr x $30/hr	240	Reporting requirements	NI		
Training of operators: 4 operators, 10 hr at $30/hr	1,200	Solid waste disposal fees and materials (145,920 lb/yr at $0.08 lb)	16,261	Test/analyze waste streams, 4 TCLPs/yr	1,500		
		Consumables and supplies (60 yd^3 SACON)	17,820	Medical exams (including loss of productive labor)	NI		
		Equipment maintenance	NI	Waste transportation (on and off site)	[a]-		
				OSHA/EHS training	960		

[a]Included in hazardous waste disposal fee.

NA = Not applicable.
NI = No increase over current costs.

Direct Process Costs. The initial equipment purchase estimates were based upon equipping a 200-foot wide, 20-lane, outdoor 25-meter range with SACON. The estimate was based upon the need for 60 yd^3 of 90-lb/ft^3 polypropylene SACON to provide an adequate backstop. The preparation would entail excavating 6 inches of soil from a 200- by 5-foot pad as well as adding and compacting gravel. Site evaluation and equipment integration costs included in the estimate were conducting a NEPA evaluation, surveying, conducting a utility avoidance sweep, and modifying operational procedures. Assumptions were made that a record of environmental consideration would be sufficient to satisfy NEPA requirements and that surveying, utility avoidance, and modifying operational procedures would be similar for the implementation of the various technologies. The installation estimate was based upon a four-man requirement with each barrier being built in 2.5 hours. Ten hours of initial operator training were assumed to be required for the four-man team. The training would include new equipment, environmental, and OSHA training.

Annual Operation and Maintenance Activity. Cost estimates were based upon utilizing existing ATC labor and disposal mechanisms, except as noted otherwise. Weekly PMCS requirements would entail a visual inspection and potentially measuring penetration distances to ensure adequate barrier depth remained. The weekly PMCS was assumed to take about 30 minutes to complete. Durability testing indicated block rotations would be required after 7,100 rounds had been fired. Under the 30,000-rounds-per-lane scenario, this equated to a need to replace and dispose of worn SACON blocks quarterly. Removing, replacing, and restacking the SACON walls was estimated to require a four-man crew approximately 4 hours to complete per barrier. The actual number of rotations would be less with less concentrated bullet impacts. Solid waste disposal estimates were based upon the results of the durability testing and equated to the removal of eight full blocks per barrier per quarter. Solid waste disposal rates were chosen over hazardous rates based upon analysis of debris at the field demonstration sites. The consumable supply estimate was based upon the manufacture of 60 cubic yards of SACON to serve as replacement blocks. Two hours of equipment refresher training for four range workers was assumed at a cost of $240 annually.

Environmental Activity and Other Costs. Development of environmental procedures and the subsequent maintenance of these procedures were estimated at 24 hours annually at a cost of $45 per hour. Solid waste management costs are, in general, proportional to the number of waste turn-in events. Solid waste management costs were based upon a 1-hour quarterly inspection followed up with 1 hour of associated paperwork corresponding to each waste turn-in event. Execution of sampling and analysis was estimated based upon four TCLP metals analyses per year. Four analytical efforts were deemed necessary to prove each turn-in was not RCRA hazardous based upon lead characteristics. Training to ensure compliance with OSHA and environmental requirements was estimated at 8 hours per person at an annual cost of $960. Overhead for ordering materials and the like was estimated at $1000 annually. A rough estimate for final disposal cost was made by summing installation costs and disposal costs for all SACON material as a solid waste.

Moderate Range Usage. Table 6-2 provides expected operational costs (without recycling) for full-scale use of the SACON technology based upon an outdoor 25-meter range application with 20 lanes, each lane receiving 15,000 rounds annually. Start-up and final disposal costs were assumed to be constant regardless of throughput. Some of the annual operation costs were reduced to reflect the impact of the moderate range utilization. With roughly a 7,500-round interval before block maintenance is required, decreasing usage to 15,000 rounds per lane would reduce the maintenance frequency from quarterly to semiannual. The consumable supplies, waste disposal, and block replacement estimates presented in Table 6-1 were reduced 50 percent accordingly. Environmental activity costs will also be reduced somewhat by decreased range utilization as a result of less frequent disposal actions. The solid waste management and analytical costs presented in Table 6-1 were also reduced by 50 percent.

Low Range Usage. Table 6-3 provides expected operational costs (without recycling) for full-scale use of the SACON technology based upon an outdoor 25-meter range application with 20 lanes, each lane receiving 7,500 rounds annually. Start-up and final disposal costs were assumed to be constant regardless of throughput. Some of the annual operation costs were reduced to reflect impact of the moderate range utilization. With roughly a 7,500 round interval before block maintenance is required, decreasing usage to 7,500 rounds per lane would reduce major maintenance to an annual requirement. The consumable supplies, waste disposal, and block replacement estimates shown in Table 6-1 were reduced 75 percent, accordingly. Environmental activity costs will also be reduced somewhat by decreased range utilization as a result of less frequent disposal actions. The solid waste management and analytical costs shown in Table 6-1 were also reduced by 75 percent.

6.2 Cost Comparison to Conventional and Other Technologies

SACON, when used in a backstop-type application, compares directly with COTS bullet traps. The function of these COTS bullet traps is to stop the bullet and contain the bullet debris within the trap. The use of SACON, as well as COTS bullet traps, is also comparable to the use of soil berms on ranges. Soil berms are a conventional technology in use at many Department of Defense (DOD) ranges to terminate the flight of bullets.

TABLE 6-2. SACON COSTS - 25-METER RANGE, 20 LANES, EACH RECEIVING 15,000 ROUNDS PER YEAR

Direct Process Costs				Annual Environmental Activity Cost		Other Cost	
Start-Up		Annual Operation and Maintenance					
Activity	$	Activity	$	Activity	$	Activity	$
Equipment purchase (60 yd^3 SACON)	17,820	Labor to maintain	19,950	Solid waste management	180	Final disposal	17,664
Equipment integration/ site evaluation	3,440	Miscellaneous overhead (ordering supplies, etc.)	1,000			Productivity/cycle time	Unchanged
Site preparation: 5-day skid loader rental; gravel; 3 laborers, 40 hr at $30/hr	4,871	Utilities	NA	Environmental management plan development and maintenance, Environmental Protection Specialist, 24 hr at $45/hr	1,080	Worker injury claims and health costs	NI
Installation: 2.5 hours x 4 laborers x $30/hr x 20 lanes	6,000	Operator refresher training (4 persons x 2 hr x $30 hr	240	Reporting requirements	NI		
Training of operators: 4 operators, 10 hr at $30/hr	1,200	Solid waste disposal fees and materials (72,960 lb/yr at $0.08/lb)	5,837	Test/analyze waste streams, 2 TCLPs/yr	750		
		Consumables and supplies (30 yd^3 SACON)	8,910	Medical exams (including loss of productive labor)	NI		
		Equipment maintenance	NI	Waste transportation (on and off site)	[a]-		
				OSHA/EHS training	960		

[a]Included in hazardous waste disposal fee.

NA = Not applicable.
NI = No increase over current costs.

TABLE 6-3. SACON COSTS - 25-METER RANGE, 20 LANES, EACH RECEIVING 7,500 ROUNDS PER YEAR

Direct Process Costs				Annual Environmental Activity Cost		Other Cost	
Start-Up		Annual Operation and Maintenance					
Activity	$	Activity	$	Activity	$	Activity	$
Equipment purchase (60 yd^3 SACON)	17,820	Labor to maintain	10,350	Solid waste management	90	Final disposal	17,664
Equipment integration/ site evaluation	3,440	Miscellaneous overhead (ordering supplies, etc.)	1,000			Productivity/cycle time	Unchanged
Site preparation: 5-day skid loader rental; gravel; 3 laborers, 40 hr at $30/hr	4,871	Utilities	NA	Environmental management plan development and maintenance, Environmental Protection Specialist, 24 hr at $45/hr	1,080	Worker injury claims and health costs	NI
Installation: 2.5 hours x 4 laborers x $30/hr x 20 lanes	6,000	Operator refresher training (4 persons x 2 hr x $30/hr	240	Reporting requirements	NI		
Training of operators: 4 operators, 10 hr at $30/hr	1,200	Solid waste disposal fees and materials (36,480 lb/yr at $0.08/lb)	2,919	Test/analyze waste streams, 1 TCLP/yr	375		
		Consumables and supplies (15 yd^3 SACON)	4,455	Medical exams (including loss of productive labor)	NI		
		Equipment maintenance	NI	Waste transportation (on and off site)	[a]-		
				OSHA/EHS training	960		

[a]Included in hazardous waste disposal fee.

NA = Not applicable.
NI = No increase over current costs.

6.2.1 Conventional Earth Berm Technology Costs

There are approximately 1800 active DOD small arms ranges. The number of these ranges that employ conventional soil berms is unknown. The primary purpose of conventional earth berms has been to terminate the flight of bullets. As a secondary benefit, berms also serve to concentrate bullet deposition. In the past, the life cycle of the berm has been virtually infinite with appropriate soil replenishment. With the advent of the Range Rule, the useful life of the berm will likely be proportional to the time period resulting in off-range migration of metals. A berm's ability to control metal dispersion and localize metals varies with soil type and berm shape. Depending on lead mobility and regulatory constraints which may be placed on range operations, cleanup of metals deposited in and around the soil berms may be required. The frequency of cleanups will directly impact the cost effectiveness of this conventional technology. In order to assess the impact of cleanup frequency upon operational cost, three scenarios were developed by USAEC for at-risk ranges. The three scenarios predicted cleanup frequency based upon lead migration rates. At-risk ranges were defined for comparison purposes as ranges where lead migration (through aerial, surface water, and/or groundwater transport) may result in regulatory action being taken that affects use or operation of the range. AEC has concluded that five parameters contribute to assessing the overall risk associated with lead migration from a small arms range. These parameters are ammunition mass-fired on the range, corrosion, aerial transport, surface water transport, and groundwater transport. These parameters can be qualitatively assessed using AEC's Range Evaluation Software Tool (REST) (ref 23).

Based upon transport risk, differing cleanup or maintenance activities may be required to prevent lead migration off range. The first scenario is a low-risk range. A low-risk range, where lead transport is not likely to occur, is defined to require cleanup only when the range is scheduled for closure. The second scenario is a medium-risk range. A medium- risk range is assumed to require intermediate lead removal maintenance actions at 15-year intervals. The third scenario is a high-risk range. A high-risk range is defined as requiring intermediate lead removal maintenance actions as frequently as once every 5 years.

The volumes of soil requiring treatment used in this comparison were based on expected treatment requirements for heavy metal-contaminated soils originating from a 20-lane 25-meter range. The soil requiring treatment would likely originate from immediately in front of, within, and immediately behind the berm. The soil volume between the firing line and the foot of the berm was based upon an area of 61 by 30 meters with a required cleaning depth of 1 meter. The entire berm section will likely require cleaning. The berm was assumed to be 61 meters long. The dimensions of the berm's cross section were defined as 2 meters high and 5 meters wide on the top of the berm with a 30° side slope. The soil immediately behind the berm was also assumed to require treatment. This volume was estimated to encompass 61 by 30 meters by 1 meter deep.

Table 6-4 summarizes projected technology costs for the operation of an outdoor 20-lane 25-meter range employing conventional berm bullet-trapping technology. Since start-up costs are constant and annual cost variations appear minor, data presented in Table 6-4 will be used for comparison at the low, moderate, and high throughput levels. Cleanup frequency and soil volumes appear to be the cost drivers. The source of the data presented in Table 6-4 is mixed between interviews with range managers and engineering judgment.

Direct Process Costs. Site evaluation and equipment integration costs included in the estimate were conducting a NEPA evaluation, surveying, utility avoidance sweep, and modifying operational procedures. Assumptions were made that a record of environmental consideration would be sufficient to satisfy NEPA requirements and that surveying, utility avoidance, and modifying operational procedures would be similar for the implementation of the various technologies. Initial installation estimates were based upon constructing an earthen berm, 80 meters long by 2 meters high by 5 meters wide at the top, to trap bullets on a 20-lane, outdoor 25-meter range. The construction cost estimates included labor, material, and equipment costs (ref RS Means Building Construction Costs Data). Construction processes included hauling, placing, and compacting the soil into a berm. Equipment requirements were assumed to include dump trucks, a bulldozer, and a compaction machine. A 20-mile round trip hauling distance was assumed. Completion of the berm construction was estimated in 3 weeks. Initial operator training was assumed to include only OSHA training.

Annual Operation and Maintenance Activity. Cost estimates were based primarily upon data gathered through interviews with Fort Jackson range personnel (ref 22). Monthly PMCS requirements would entail a visual inspection to ensure the fitness of the berm, i.e., evidence of erosion. The monthly PMCS was assumed to take about 30 minutes to complete at a cost of $30 per hour. The PMCS cost was estimated at $180 annually. Interviews with range personnel at Fort Jackson revealed a need to repair the berm approximately semiannually. The semiannual maintenance consists of repairing cavities in the berm created by repeated and concentrated bullet impacts. The repair is made by filling the pockets with soil and compacting using hand tools. The maintenance action is completed by seeding and fertilizing to stabilize the repaired area. For the semiannual maintenance task, two range workers were assumed to complete a semiannual maintenance event in 8 hours. The annual labor cost to complete two semiannual maintenance events was estimated to be $960. Other periodic maintenance includes grass cutting. Four grass cutting events were assumed per year. The cost of grass cutting was estimated at $960 per year. Consumable supplies, including soil, grass seed, fertilizer, fuel, and hand tools, were estimated to cost $500 annually. No annual waste disposal costs are incurred through present range operations.

Environmental Activity and Other Costs. No annual environmental costs are incurred by current range practices. Audits, document maintenance, environmental management plans, sampling and analysis, and environmental training are not currently required to operate a range. A final disposal cost was estimated based upon ex-situ treatment of the lead-contaminated soil. A cost of $164 per ton was used to estimate the cost of soil remediation (ref 7). For estimation purposes, the soil requiring remediation was defined as 61- by 25- by 1-meter soil volume in front of, the entire volume in within, and the 30- by 61- by 1-meter volume immediately behind the berm.

TABLE 6-4. CONVENTIONAL EARTH BERM COSTS 25-METER RANGE, 20 LANES, EACH RECEIVING 7,500 TO 30,000 ROUNDS PER YEAR

Direct Process Costs				Annual Environmental Activity Cost		Other Cost	
Start-Up		Annual Operation and Maintenance					
Activity	$	Activity	$	Activity	$	Activity	$
Equipment purchase	0	Labor to maintain (PMCS/berm repair/cut grass)	2,100	Hazardous waste management	0	Final disposal	1,176,000
Equipment integration/ site evaluation	3,440				0	Productivity/ cycle time	Unchanged
Site preparation/ construction:	55,000	Utilities	NA	Environmental management plan development and maintenance	0	Worker injury claims and health costs	NI
				Reporting requirements	NI		
Training of operators: 4 operators, 4 hr at $30/hr	480	Hazardous waste disposal fees and materials (lb/yr at $0.12/lb)	0	Test/analyze waste streams	0		
		Consumables and supplies (grass seed, fertilizer, soil)	500	Medical exams (including loss of productive labor)	NI		
		Equipment maintenance	NI	Waste transportation (on and off site)	0		
				OSHA training	480		

NA = Not applicable.
NI = No increase over current costs.

6.2.2 COTS Bullet Trap Costs

There are a number of different types of bullet traps available on the market. The bullet traps differ in the manner in which they impart friction on the bullet to stop its flight. Generally, bullet traps accomplish this through three basic designs: impact, deceleration, or friction.

In order to assess the potential benefits of COTS bullet traps to range operations, AEC initiated a test program concurrently with the SACON test program. Three of the most popular COTS bullet traps were tested by ATC as part of TECOM Project No. 1-CO-160-000-192. The traps selected for testing represented the friction and deceleration categories. Impact-type traps were not tested due to their inability to contain bullet debris. Direct and indirect cost extrapolations were made based upon actions related to the concurrent COTS demonstration, other published DOD evaluations, and engineering judgment.

6.2.2.1 GRFT Technology. A description and photographs of the GRFT technology appear in Section 5.3. Table 6-5 summarizes projected technology implementation costs for the granular rubber bullet-trapping technology.

Direct Process Costs. Initial equipment purchase and installation estimates were based upon a manufacturer's quote for equipping a 200-foot wide, 20-lane, outdoor 25-meter range (ref 67). Site preparation estimates were based upon preparing a range at ATC to accept the commercial trap. The preparation would entail the construction of a 200-foot long by 18.75-foot wide by 6-inch thick concrete pad. Site evaluation and equipment integration costs included in the estimate were conducting an NEPA evaluation, surveying, utility avoidance sweep, and modifying operational procedures. Assumptions were made that a record of environmental consideration would be sufficient to satisfy NEPA requirements and that surveying, utility avoidance, and modifying operational procedures would be similar for the implementation of the various technologies. Initial operator training was assumed to include new equipment, environmental, and OSHA training.

TABLE 6-5. GRANULAR RUBBER TECHNOLOGY COSTS 25-METER RANGE, 20 LANES, EACH RECEIVING 30,000 ROUNDS PER YEAR

Direct Process Costs				Environmental Activity Costs		Other Costs	
Start-Up		Annual Operation and Maintenance					
Activity	$	Activity	$	Activity	$	Activity	$
Equipment purchase	192,645	Labor to maintain (PMCS/Scheduled Maintenance	5,220	Hazardous waste management	90		
Equipment integration/ site evaluation	3,440	Remove bullet debris/reuse granular rubber	3,600 (every 2 years)			Productivity/ cycle time	Unchanged
Site preparation:	11,700	Utilities	NA	Environmental management plan development and maintenance, Environmental Protection Specialist, 8 hr at $45/hr	1,080	Worker injury claims and health costs	NI
Installation: (contract)	20,050	Equipment refresher training	240	Reporting requirements	NI	Final disposal	50050
Training of operators: 4 operators, 10 hr at $30/hr	1,200	Hazardous waste disposal fees and materials (weight of covers 530 lb/yr at $0.12/lb)	64	Test/analyze waste streams, 1 TCLP/yr	375		
		Consumables and supplies	11,700	Medical exams (including loss of productive labor)	NI		
		Equipment maintenance	NI	Waste transportation (on and off site)	[a]-		
		Overhead associated with process	1,000	OSHA/EHS training	960		

[a]Included in hazardous waste disposal fee.

NA = Not applicable.
NI = No increase over current costs.

Annual Operation and Maintenance Activity. Cost estimates were based upon utilizing existing ATC labor and disposal mechanisms, except as noted otherwise. Weekly PMCS requirements would entail a visual inspection to ensure proper granular rubber height and fitness of the rubber cover. The weekly PMCS was assumed to take one range worker about 30 minutes to complete. The annual cost to complete the weekly PMCS requirements was estimated at $780. During testing at ATC, patching of the rubber cover was required after 3200 rounds were fired. Under the 30,000-rounds-per-lane scenario, this equates to a need for approximately 200 patches per year. The actual number of patches would be less with less concentrated bullet impacts. Time to patch was estimated at 15 minutes per patch, utilizing two range workers at $30 per hour. An annual labor cost to perform patching was estimated to be $3000. Complete replacement of the rubber cover was assumed to be required yearly. The effort was estimated to require two range workers 24 hours each to complete for an annual labor cost of $1440. Removal of bullet debris was estimated by the manufacturer to be required every 50,000 to 70,000 rounds. Cost for the removal of the debris was estimated roughly at $3600 based upon utilizing three range workers for 40 hours each. At the 30,000-round-per-lane usage rate, a two-year maintenance cycle was assumed. Consumable supplies included in the estimate were rubber (1 percent of the original weight, $500), patch kits ($1,200), and rubber covers ($10,000). Annual waste generation rates were based upon the yearly disposal of the rubber covers only. Disposal of the granular rubber was not considered because the useful life of the rubber is not known. As part of the metals reclamation process, the degraded rubber is separated from the metal and returned to the trap. Replacement rubber is added as needed to maintain proper operating levels. Two hours of equipment refresher training for four range workers was assumed at a cost of $240 annually. Overhead for ordering materials, preparing for maintenance, and the like was estimated at $1000 annually.

Environmental Activity and Other Costs. Development and maintenance of range operational procedures by an Environmental Protection Specialist were estimated to cost $1080 annually. The procedures would outline range procedures and delineate responsibilities necessary to ensure bullet-trap operations were environmentally compliant. The $1080 figure was based upon 24 hours of annual effort at $45 per hour. The annual cost of hazardous waste management was estimated at $90 based upon the utilization of 2 hours of an Environmental Protection Specialist's labor at $45 per hour. The hazardous waste management costs were based upon a 1-hour range inspection followed up with 1 hour of associated paperwork corresponding to each waste turn-in action. The purpose of the inspection would be to ensure that proper techniques are being followed to ensure operations are RCRA compliant and in accordance with the established range procedures. Execution of sampling and analysis to characterize the waste stream was estimated based upon the cost to complete one TCLP metals analysis per year. Analytical costs were estimated to be $350 per year. Annual training to ensure compliance with OSHA and environmental requirements was estimated at 8 hours per person for four range workers. Training costs were estimated to be $960 annually. A final disposal cost was estimated by summing the installation costs and hazardous waste disposal costs. Waste costs were based upon disposing of the entire mass of the trap as a hazardous waste.

Moderate Range Usage. Table 6-6 provides expected operational costs for a full-scale use of the GRFT technology based upon an outdoor 25-meter range application with 20 lanes, each lane receiving 15,000 rounds annually. Start-up and final disposal costs were assumed to be constant regardless of throughput. Some of the annual operation costs were reduced to reflect impact of the moderate range utilization. The frequency of the metals reclamation activity was reduced to four-year intervals. The consumable supplies and waste disposal estimates presented in Table 6-5 were reduced 50 percent accordingly. Environmental activity costs will also be reduced somewhat by decreased range utilization as a result of less frequent disposal actions. The hazardous waste management and analytical costs presented in Table 6-5 were also reduced by 50 percent.

Low Range Usage. Table 6-7 provides expected operational costs for a full-scale use of the GRFT technology based upon an outdoor 25-meter range application with 20 lanes, each lane receiving 7500 rounds annually. Start-up and final disposal costs were assumed to be constant regardless of throughput. Some of the annual operation costs were reduced to reflect impact of the low range utilization. The frequency of the metals reclamation activity was reduced to every eight years. The consumable supplies and waste disposal estimates presented in Table 6-5 were reduced 75 percent accordingly. Environmental activity costs will also be reduced somewhat by decreased range utilization as a result of less frequent disposal actions. The hazardous waste management and analytical costs presented in Table 6-5 were also reduced by 75 percent.

6.2.2.2 Block Rubber Friction Trap Technology. A description and photographs of this technology appear in Section 5.3. Table 6-8 summarizes projected full-scale technology implementation costs for the block rubber bullet-trapping technology.

Direct Process Costs. Initial equipment purchase and installation estimates were based upon a manufacturer's quote for equipping a 200-foot wide, 20-lane, outdoor 25-meter range (ref 67). Site preparation estimates were based upon preparing a range at ATC to accept the commercial trap. The preparation would entail the construction of a 200-foot long by 5-foot wide by 8-inch thick concrete pad. Site evaluation and equipment integration costs included in the estimate were conducting an NEPA evaluation, surveying, conducting a utility avoidance sweep, and modifying operational procedures. Assumptions were made that a record of environmental consideration would be sufficient to satisfy NEPA requirements and that surveying, utility avoidance, and modifying operational procedures would be similar for the implementation of the various technologies. Initial operator training was assumed to include new equipment, environmental, and OSHA training.

TABLE 6-6. GRANULAR RUBBER TECHNOLOGY COSTS 25-METER RANGE, 20 LANES, EACH RECEIVING 15,000 ROUNDS PER YEAR

Direct Process Costs				Environmental Activity Costs		Other Costs	
Start-Up		Annual Operation and Maintenance					
Activity	$	Activity	$	Activity	$	Activity	$
Equipment purchase	192,645	Labor to maintain (PMCS/scheduled maintenance)	3,000	Hazardous waste management	45		
Equipment integration/ site evaluation	3,440	Remove bullet debris/reuse granular rubber	3,600 (every 4 years)			Productivity/ cycle time	Unchanged
Site preparation:	11,700	Utilities	NA	Environmental management plan development and maintenance, Environmental Protection Specialist, 8 hr at $45/hr	1,080	Worker injury claims and health costs	NI
Installation: (contract)	20,050	Equipment refresher training	240	Reporting requirements	NI	Final disposal	50,050
Training of operators: 4 operators, 10 hr at $30/hr	1,200	Hazardous waste disposal fees and materials	32	Test/analyze waste streams	188		
		Consumables and supplies	5,850	Medical exams (including loss of productive labor)	NI		
		Equipment maintenance	NI	Waste transportation (on and off site)	[a]-		
		Overhead associated with process	1,000	OSHA/EHS training	960		

[a]Included in hazardous waste disposal fee.

NA = Not applicable.
NI = No increase over current costs.

TABLE 6-7. GRANULAR RUBBER TECHNOLOGY COSTS 25-METER RANGE, 20 LANES, EACH RECEIVING 7,500 ROUNDS PER YEAR

Direct Process Costs				Environmental Activity Cost		Other Costs	
Start-Up		Annual Operation and Maintenance					
Activity	$	Activity	$	Activity	$	Activity	$
Equipment purchase	192,645	Labor to maintain (PMCS/scheduled maintenance)	1,890	Hazardous waste management	23		
Equipment integration/ site evaluation	3,440	Remove bullet debris/reuse granular rubber	3,600 (every 8 years)			Productivity/ cycle time	Unchanged
Site preparation:	11,700	Utilities	NA	Environmental management plan development and maintenance, Environmental Protection Specialist, 8 hr at $45/hr	1,080	Worker injury claims and health costs	NI
Installation: (contract)	20,050	Equipment refresher training	240	Reporting requirements	NI	Final disposal	50,050
Training of operators: 4 operators, 10 hr at $30/hr	1,200	Hazardous waste disposal fees and materials	16	Test/analyze waste streams	94		
		Consumables and supplies	2,925	Medical exams (including loss of productive labor)	NI		
		Equipment maintenance	NI	Waste transportation (on and off site)	[a]-		
		Overhead associated with process	1,000	OSHA/EHS training	960		

[a]Included in hazardous waste disposal fee.

NA = Not applicable.
NI = No increase over current costs.

TABLE 6-8. BLOCK RUBBER TECHNOLOGY COSTS - 25-METER RANGE, 20 LANES, EACH RECEIVING 30,000 ROUNDS PER YEAR

Direct Process Costs				Environmental Activity Costs		Other Costs	
Start-Up		Annual Operation and Maintenance					
Activity	$	Activity	$	Activity	$	Activity	$
Equipment purchase	11,2175	Labor to maintain	12,750	Hazardous waste management	900		
Equipment integration/site evaluation[a]	3,440	Equipment refresher training	240			Productivity/ cycle time	Unchanged
Site preparation:	4,330	Utilities	NA	Environmental management plan development and maintenance, Environmental Protection Specialist, 8 hr at $45/hr	1,080	Worker injury claims and health costs	NI
Installation:	11,750			Reporting requirements	NI	Final disposal	30,123
Training of operators: 4 operators, 10 hr at $30/hr	1,200	Hazardous waste disposal fees and materials (23,203 lb/yr at $0.12/lb)	2,784	Test/analyze waste streams, 4 TCLPs/yr	1,500		
		Consumables and supplies	13,890	Medical exams (including loss of productive labor)	NI		
		Equipment maintenance	NI	Waste transportation (on and off site)	[a]-		
		Overhead associated with process	1,000	OSHA/EHS training	960		

[a]Included in hazardous waste disposal fee.

NA = Not applicable.
NI = No increase over current costs.

Annual Operation and Maintenance Activity. Cost estimates were based upon utilizing existing ATC labor and disposal mechanisms, except as noted otherwise. Weekly PMCS requirements would entail a visual inspection to ensure adequate block depth remained and general fitness of the trap. The weekly PMCS was assumed to take about 30 minutes to complete at an annual cost of $780. During testing at ATC, blocks received 3,200 rounds without reaching the back panels. Under the 30,000-rounds-per-lane scenario, a block life of 3,200 rounds would equate to a need for approximately 200 block replacements per year. The actual number of block replacements would be less with less concentrated bullet impacts. Time to replace a block was estimated at 15 minutes per block and was considered a two-man task. Five rubber panels were assumed to be replaced yearly. The mass of 200 blocks and 600,000 bullets were combined to yield an annual disposal requirement. Consumable supplies included in the estimate were 200 rubber blocks and five rubber back panels. Two hours of equipment refresher training for four range workers was assumed at a cost of $240 annually.

Environmental Activity and Other Costs. Environmental management costs for the block rubber trap would, in general, be higher than those for SACON because of increased maintenance frequencies. More waste turn-ins equate to more paperwork and possibly more analytical testing to characterize the waste stream adequately. For estimation purposes, the cost of sampling and analyzing four TCLP samples was included to establish generator knowledge of the waste stream characteristics. The annual cost of sampling and analysis was estimated to be $1500. The frequency of waste generation with the rubber block technology appears to be approaching monthly intervals. The cost to ensure compliance with RCRA and range procedures would thus be increased by approximately a factor of 6 when compared to SACON. The annual cost of completing hazardous waste management functions such as waste turn-in documentation, compliance inspections, and associated paperwork necessary to ensure RCRA compliance was estimated to cost $900 annually. The cost was based upon a 2-hour inspection and documentation effort being completed commensurate with each hazardous waste turn-in. Annual training to ensure compliance with OSHA and environmental requirements was estimated at 8 hours per person for four range workers. Training costs were estimated to be $1200 annually. Overhead for ordering materials, preparing for maintenance, and the like was estimated at $1000 annually. Final disposal was estimated by summing the installation costs and hazardous waste disposal costs based upon the entire mass of the trap.

Moderate Range Usage. Table 6-9 provides expected operational costs for a full-scale use of the rubber block technology based upon an-outdoor 25-meter range application with 20 lanes, each lane receiving 15,000 rounds annually. Start-up and final disposal costs were assumed to be constant regardless of throughput. Some of the annual operation costs were reduced to reflect impact of the moderate range utilization. The frequency of block replacement was reduced from monthly to every other month. The consumable supplies and waste disposal estimates presented in Table 6-8 were reduced 50 percent accordingly. Environmental activity costs will also be reduced somewhat by decreased range utilization as a result of less frequent disposal actions. The hazardous waste management and analytical costs presented in Table 6-8 were also reduced by 50 percent.

TABLE 6-9. BLOCK RUBBER TECHNOLOGY COSTS - 25-METER RANGE, 20 LANES, EACH RECEIVING 15,000 ROUNDS PER YEAR

Direct Process Cost							
Start-Up		Annual Operation and Maintenance		Environmental Activity Costs		Other Costs	
Activity	$	Activity	$	Activity	$	Activity	$
Equipment purchase	11,2175	Labor to maintain	6,765	Hazardous waste management	450		
Equipment integration/ site evaluation[a]	3,440	Equipment refresher training	240			Productivity/cycle time	Unchanged
Site preparation:	4,330	Utilities	NA	Environmental management plan development and maintenance, Environmental Protection Specialist, 8 hr at $45/hr	1,080	Worker injury claims and health costs	NI
Installation:	11,750			Reporting requirements	NI	Final disposal	30,123
Training of operators: 4 operators, 10 hr at $30/hr	1,200	Hazardous waste disposal fees and materials (23,203 lb/yr at $0.12/lb)	1,392	Test/analyze waste streams, 2 TCLPs/yr	750		
		Consumables and supplies	6,945	Medical exams (including loss of productive labor)	NI		
		Equipment maintenance	NI	Waste transportation (on and off site)	[a]-		
		Overhead associated with process	1,000	OSHA/EHS training	960		

[a]Included in hazardous waste disposal fee.

NA = Not applicable.
NI = No increase over current costs.

Low Range Usage. Table 6-10 provides expected operational costs for a full-scale use of the block rubber technology based upon an outdoor 25-meter range application with 20 lanes, each lane receiving 7,500 rounds annually. Start-up and final disposal costs were assumed to be constant regardless of throughput. Some of the annual operation costs were reduced to reflect impact of the low range utilization. The frequency of block replacement was reduced to semiannual. The consumable supplies and waste disposal estimates presented in Table 6-8 were reduced 75 percent accordingly. Environmental activity costs will also be reduced somewhat by decreased range utilization as a result of less frequent disposal actions. The hazardous waste management and analytical costs presented in Table 6-8 were also reduced by 75 percent.

6.2.2.3 Deceleration Trap Technology. A description and photographs of the deceleration trap technology appear in Section 5.3. Table 6-11 summarizes projected technology implementation costs for the deceleration bullet- trapping technology.

Direct Process Costs. Initial equipment purchase and installation estimates were based upon a manufacturer's quote for equipping a 200-foot wide, 20-lane, outdoor 25-meter range (ref 67). Site preparation estimates were based upon preparing a range at ATC to accept the commercial trap. The preparation would entail the construction of a 200-foot wide by 21-foot deep by 6-inch thick concrete pad and providing electrical power. Site evaluation and equipment integration costs included in the estimate were conducting an NEPA evaluation, surveying, conducting a utility avoidance sweep, and modifying operational procedures. Assumptions were made that a record of environmental consideration would be sufficient to satisfy NEPA requirements and that surveying, utility avoidance, and modifying operational procedures would be similar for the implementation of the various technologies. Initial operator training was assumed to include new equipment, environmental, and OSHA training.

TABLE 6-10. BLOCK RUBBER TECHNOLOGY COSTS - 25-METER RANGE, 20 LANES, EACH RECEIVING 7,500 ROUNDS PER YEAR

Direct Process Costs				Environmental Activity Costs		Other Costs	
Start-Up		Annual Operation and Maintenance					
Activity	$	Activity	$	Activity	$	Activity	$
Equipment purchase	11,2175	Labor to maintain	3,773	Hazardous waste management	225		
Equipment integration/ site evaluation[a]	3,440	Equipment refresher training	240			Productivity/ cycle time	Unchanged
Site preparation:	4,330	Utilities	NA	Environmental management plan development and maintenance, Environmental Protection Specialist, 8 hr at $45/hr	1,080	Worker injury claims and health costs	NI
Installation:	11,750			Reporting requirements	NI	Final disposal	30,123
Training of operators: 4 operators, 10 hr at $30/hr	1,200	Hazardous waste disposal fees and materials	696	Test/analyze waste streams, 1 TCLP/yr	375		
		Consumables and supplies	3,473	Medical exams (including loss of productive labor)	NI		
		Equipment maintenance	NI	Waste transportation (on and off site)	[a]-		
		Overhead associated with process	1,000	OSHA/EHS training	960		

[a]Included in hazardous waste disposal fee.

NA = Not applicable.
NI = No increase over current costs.

TABLE 6-11. DECELERATION TRAP TECHNOLOGY COSTS - 25-METER RANGE, 20 LANES, EACH RECEIVING 30,000 ROUNDS PER YEAR

Direct Process Costs				Environmental Activity Costs		Other Costs	
Start-Up		Annual Operation and Maintenance					
Activity	$	Activity	$	Activity	$	Activity	$
Equipment purchase	259,890	Labor to maintain	Unknown	Hazardous waste management	Unknown		
Equipment integration/ site evaluation	3,440					Productivity/cycle time	Unchanged
Site preparation including utilities:	37,000	Utilities (electric)	Unknown	Environmental management plan development and maintenance	1,080	Worker injury claims and health costs	NI
Installation:	14,500	Overhead associated with process	Unknown	Reporting requirements	NI	Final disposal	340,500
Training of operators: 4 operators, 12 hr at $30/hr	1,440	Hazardous waste disposal fees and materials	Unknown	Test/analyze waste streams,	Unknown		
		Consumables and supplies	Unknown	Medical exams (including loss of productive labor)	NI		
				Waste transportation (on and off site)	[a]-		
		Equipment refresher training	480	OSHA/EHS training	960		

[a]Included in hazardous waste disposal fee.

NA = Not applicable.
NI = No increase over current costs.

Annual Operation and Maintenance Activity. Cost estimates were based upon utilizing existing ATC labor and disposal mechanisms, except as noted otherwise. Daily PMCS requirements would entail a visual inspection to ensure adequate filter differential pressure and general fitness of the trap. The daily PMCS was assumed to take about 30 minutes to complete at an annual cost of $3750. The cost was based upon an estimated 250 training days per year. Testing at ATC was terminated prior to determining the durability of the trap when exposed to military ammunition. The life of the plates, deceleration chamber, and DCU has not been determined by government testing. It appears that only a minimal amount of hazardous waste would be generated by the operation. The hazardous waste would consist primarily of spent filters and materials used to clean accumulated dust. Bullet debris and metal panels following a render-safe would likely be reclaimed as a scrap metal. A 4-hour annual equipment training session for four range workers was assumed. The duration of the training was extended because of the additional complexity of the trap. Overhead for ordering materials, preparing for maintenance, and the like was estimated at $1000 annually. Annual operation and maintenance costs were not included in Table 6-11 due to the unknown durability and required maintenance frequency of the trap.

Environmental Activity and Other Costs. A $1080 annual cost to develop and maintain range operational procedures was assumed to be constant regardless of the bullet-trapping technology chosen. The annual cost of hazardous waste management is unknown. Annual training to ensure compliance with OSHA and environmental requirements was estimated at 8 hours per person for four range workers. Training costs were estimated to be $960 annually. Final disposal was estimated by summing the installation costs ($14,500) and soil treatment costs ($326,000). The cost of the final disposition of the metal trap was not considered because of potentially limited scrap value. Soil treatment costs are likely to be incurred as result of a failure to contain dust emissions. For estimation purposes, the soil requiring remediation was defined as 61- by 20- by 1-meter soil volume. It was assumed that interim remediation efforts would not be required to maintain compliance with environmental regulations. Final disposal was estimated based upon ex-situ treatment of the lead-contaminated soil. A cost of $164 per ton was used to estimate the cost of soil remediation (ref 7). The mass of the soil was assumed to be 1.63 tons per cubic meter of soil.

Moderate and low range usage estimates were not made due to a lack of durability data necessary to extrapolate maintenance costs.

6.3 Cost Analysis

An annual net equivalent value (ANEV) was calculated for each of the technology alternatives. The formula used to derive the ANEV is presented in Figure 6-1 (ref 62). The ANEV calculation transforms present and future costs to annual costs for comparison purposes. Assumptions made were an interest rate of 3.65 percent (ref 61) and a 15-year life (ref 59).

$$ANEV = -(A/P)^i_n(\text{Initial Costs}) - \text{Annual Costs} - (A/F)^i_n(\text{Disposal Costs})$$

where:

$(A/P)^i_n = (i(1+i)^n)/((1+i)^n-1)$.

$(A/F)^i_n = i/((1+i)^n-1)$.

i = interest rate.

n = number of years.

Figure 6-1. ANEV formula.

Cost data presented in Tables 6-1 through 6-11 have been summarized in Tables 6-12, 6-14, and 6-16 for use in the ANEV analysis. Analysis of the data yielded to common trends. First, range utilization rates affect annual operation and environmental costs for all the technologies except for the conventional berm technology. The rationale behind this trend is simple; less usage equates to less maintenance and reduced consumable supply usage. The conventional berm maintenance would likely be reduced slightly. However, current operational methods do not generate wastes until closure. The second trend relates to a risk reduction realized by the incorporation of technologies which contain the bullet and bullet debris. If a technology localizes bullets and bullet debris, cleanup of the range will not be dependent upon transport risk.

TABLE 6-12. HIGH-USE RANGE - BULLET-TRAP TECHNOLOGY COST COMPARISON SUMMARY

Technology	Start-Up, $	Annual Operation and Maintenance, $	Annual Environmental Activity Costs, $	Disposal, $
SACON	33,331	74,471	3,900	17,664
Conventional berm	58,920	2,600	480	1,176,000
Deceleration (COTS)	316,270	No estimate	No estimate	340,500
Block rubber	132,895	30,664	4,440	30,123
Granular rubber	229,035	[a]18,224	2,505	50,050

[a]Excluding metals recovery. Metals recovery factored in as a future cost every n years.

The high-use range ANEVs derived are presented in Table 6-13.

TABLE 6-13. HIGH-USE RANGE - ANNUAL NET EQUIVALENT VALUE COMPARISON

Technology	ANEV Cost		
	Low Risk, $	Medium Risk, $	High Risk, $
Conventional	[a]14,237	68,525	406,266
SACON	82,201	82,201	82,201
Deceleration	No estimate	No estimate	No estimate
Block rubber	48,309	48,309	48,309
Granular rubber	47,707	47,707	47,707

[a]Based upon a 50-year berm life.

TABLE 6-14. MODERATE-USE RANGE - BULLET-TRAP TECHNOLOGY COST COMPARISON SUMMARY

Technology	Start-Up, $	Annual Operation and Maintenance, $	Annual Environmental Activity Costs, $	Disposal, $
SACON	33,331	35,937	2,970	17,664
Conventional berm	58,920	2,600	480	1,176,000
Deceleration (COTS)	316,270	No estimate	No estimate	340,500
Block rubber	132,895	16,342	3,240	30,123
Granular rubber	229,035	10,122	2,273	50,050

The moderate-use range ANEVs derived are presented in Table 6-15.

TABLE 6-15. MODERATE USE RANGE - ANNUAL NET EQUIVALENT VALUE COMPARISON

Technology	ANEV Cost		
	Low Risk, $	Medium Risk, $	High Risk, $
Conventional	[a]14,237	68,525	406,266
SACON	42,737	42,737	42,737
Deceleration	No estimate	No estimate	No estimate
Block rubber	32,788	32,788	32,788
Granular rubber	36,550	36,550	36,550

[a]Based upon a 50-year berm life.

TABLE 6-16. LOW-USE RANGE - BULLET-TRAP TECHNOLOGY COST COMPARISON SUMMARY

Technology	Start -Up, $	Annual Operation and Maintenance, $	Annual Environmental Activity Costs, $	Disposal, $
SACON	33,331	18,964	2,505	17,664
Conventional berm	58,920	2,600	480	1,176,000
Deceleration (COTS)	31,6270	No estimate	No estimate	340,500
Block rubber	132,895	9,182	2,640	30,123
Granular rubber	229,035	6,071	2,157	50,050

The low-use range ANEVs derived are presented in Table 6-17.

TABLE 6-17. LOW-USE RANGE - ANNUAL NET EQUIVALENT VALUE COMPARISON

	ANEV Cost		
Technology	Low Risk, $	Medium Risk, $	High Risk, $
Conventional	[a]14,237	68,525	406,266
SACON	25,299	25,299	25,299
Deceleration	No estimate	No estimate	No estimate
Block rubber	25,028	25,028	25,028
Granular rubber	31,287	31,287	31,287

[a]Based upon a 50 year berm life

Table 6-18 summarizes the ANEV calculations by presenting the lowest cost technology per category. For the low usage, medium- and high-risk categories, the block rubber and SACON had essentially the same ANEV.

TABLE 6-18. ANEV BY CATEGORY

Usage Rate	Risk		
	Low	Medium	High
High	Conventional berm	Granular rubber	Granular rubber
Moderate	Conventional berm	Block rubber	Block rubber
Low	Conventional berm	Block rubber/SACON	Block rubber/SACON

Based upon the economic data presented, the range of applicability for the SACON technology would be on ranges of medium to high risk with low- to moderate-usage rates.

7. Regulatory Issues

Routine maintenance and environmental assessment of ranges are not specifically addressed in any single Federal regulation. However, portions of different Federal regulations could be applicable in certain situations and should be considered. Federal laws such as the Clean Water Act (CWA); Safe Drinking Water Act; Resource Conservation and Recovery Act (RCRA); and the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) can be applied to active small arms ranges (ref 68). For example, in April 1997, EPA Region I relied on the Safe Drinking Water Act to stop training at the Massachusetts Military Reservation. This was based on allegations that ongoing training activities caused an imminent and substantial threat of contamination to the sole source aquifer under the impact area. A summary of each regulation's potential impact on range use is as follows:

CERCLA: Title 40 Code of Federal Regulations (CFR) Part 302, Designation, Reportable Quantities, and Notification (promulgated in response to requirements of the CERCLA and the Emergency Planning and Community Right-to-Know Act of 1986 (EPCRA)), designates lead as a hazardous substance and requires the reporting of releases to the environment. To be a reportable release under 40 CFR Part 302, the amount of the release must equal or exceed, within a 24-hour period, the reportable quantity (RQ) for the hazardous substance. Per Section 302.6, Notification Requirements, notification must be provided to EPA's National Response Center (800-424-8802) if a release occurs of 1 pound or more of solid lead particles less than or equal to 100 micrometers in mean diameter. A release of this type would be unlikely at a military small arms firing range.

Regardless of whether the RQ for lead or other contaminants has been exceeded at a range, the EPA can, under CERCLA authority, require that lead-contaminated soils and groundwater be investigated and remediated. This can include any off-site environmental contamination originating from the site, if such lead contamination has been determined to pose an unacceptable potential risk to human health or the environment.

RCRA: At operational firing ranges, lead-containing bullets are fired and eventually fall to the ground at or near the range. The EPA has determined the act of firing ammunition does not, by itself, generate a solid waste under RCRA because the ammunition is being used for its intended purpose (i.e., it has not been "discarded").

Under RCRA, removing lead-containing bullets, lead-contaminated soil, or lead-contaminated range debris from a firing range or abandoning a range containing such material may be viewed as discarding, making the removed materials solid waste subject to RCRA disposal regulations. However, the EPA has deferred to the drafters of the DOD Range Rule (discussed further below) any action on the issue of abandonment or transfer being equivalent to discarding. The DOD Range Rule proposes to address such sites according to a CERCLA-like process, rather than under RCRA authority, where risks posed to human health and environmental receptors are evaluated via site-specific investigations and risk-based remediation goals. This is currently the way the EPA Munitions Rule addresses the investigation and cleanup of active and inactive ranges. The public comment period for the DOD Proposed Rule ended in December 1997. The EPA will judge whether the DOD's Final Range Rule "adequately protects human health and the environment" after it is published.

Any RCRA-regulated solid waste destined for land disposal must be pre-evaluated for its potential environmental impact. (It is important to note that not all ranges or wastes collected/originating from ranges are necessarily going to be subject to regulation under RCRA. See below under EPA Final Munitions Rule and DOD Proposed Range Rule for further discussion.) RCRA-regulated solid wastes are deemed hazardous if they are a listed waste or exhibit any of the hazardous waste characteristics such as toxicity, ignitability, corrosivity, and reactivity. If a soil or debris sample when subject to the TCLP produces a result in excess of the regulatory limit for lead (5 milligrams per liter (parts per million)), then the waste represented by the sample becomes a characteristic hazardous waste due to its leachable lead concentration and would be subject to RCRA regulation as a hazardous waste for disposal purposes. As the pH of the lead-containing soil or debris approaches 7 (neutral) or higher (alkaline), its potential for leaching lead above 5 ppm during TCLP testing is lowered. In addition to pH, other important variables affecting the potential for leaching lead from soil or debris samples during TCLP testing are grain size and whether the lead is in elemental form or weathered corrosion products.

Certain sifting and collection activities can be used to recover lead fragments from range soils and debris. Recovered lead fragments destined for recycling are exempt from RCRA regulation. However, recovered material not destined for recycling and soil or debris handled during the recovery process may be subject to RCRA regulation as a solid waste or a hazardous waste.

According to EPA, authority exists under RCRA to compel remediation where an imminent and substantial endangerment to health or the environment (e.g., contamination of a sensitive habitat or a drinking water supply) may have been created by munitions fragments at a firing range.

While cleanup of lead from small arms firing ranges is normally controlled by CERCLA, the decision regarding which regulatory scheme applies is a fact-specific decision.

EPA Munitions Rule: Section 107 of the Federal Facility Compliance Act (FFCA) of 1992 amended RCRA by adding a new section (3004y) that required the EPA to "identify when military munitions become hazardous waste for the purposes of RCRA Subtitle C, and to provide for the safe transportation and storage of such wastes." The Military Munitions Rule (EPA Munitions Rule), published at Federal Register Vol. 62, No. 29, page 6622, 12 February 1997, responded to several key issues raised concerning the application of RCRA to military munitions. The EPA Munitions Rule is codified at 40 CFR Parts 260 through 266 and Part 270 (Subpart M, Military Munitions, is in part 266).

Under the EPA Munitions Rule, fired military munitions fragments (e.g., spent bullet fragments, debris, and unexploded ordnance) are not considered RCRA waste (i.e., a discarded material) when the munitions were used for their intended purpose, as they would be within the confines of an active or inactive firing range. Under the EPA Munitions Rule, the recovery, collection, and on-range destruction of munitions fragments from an active or inactive range during range clearance activities is also considered use for intended purpose. Although on-range collection may not by itself render the fragments RCRA waste, the removal of such materials to an off-range location or their burial on-range would be discarding and result in the generation of a solid waste (therefore a potentially hazardous waste) subject to RCRA disposal regulations. However, lead-containing munition fragments destined for off-range reclamation/recycling would be exempted from regulation as a hazardous waste under the RCRA scrap metal provision found in 40 CFR Part 261.6(a)(3)(ii).

Under the EPA Munitions Rule, fired munitions that land off-range and are not promptly retrieved have been discarded and would then be regulated as solid wastes under RCRA.

DOD Proposed Range Rule: Closed, Transferred, and Transferring Ranges Containing Military Munitions; Proposed Rule, DOD, Federal Register Vol. 62, No. 187, 26 September 1997 (DOD Range Rule) proposes a process for evaluating and selecting appropriate response actions at closed, transferred, and transferring military ranges. This rule does not apply to active ranges.

This rule was proposed in response to the EPA Munitions Rule and addresses the management of closed, transferred, and transferring ranges, which were not addressed in the EPA Munitions Rule as discussed above. If finalized, the DOD Range Rule will establish procedures for evaluating and responding to safety, human health, and environmental risks on closed, transferred, and transferring military ranges. To accomplish this, the DOD Range Rule proposes a five-part Range Response Process. This process evaluates appropriate response actions, consistent with CERCLA cleanup provisions, which evaluate actual risks posed by contaminants based on reasonably anticipated future land use. This could mean compliance with significantly different cleanup criteria than might be required under RCRA authority, which would apply if the munitions fragments at closed, transferred, and transferring ranges were designated RCRA solid wastes.

CWA: The Water Quality Act of 1987 created specific provisions for the control of surface water pollution caused by storm water runoff. Runoff from firing ranges can contain elevated levels of dissolved lead and other heavy metals, as well as particulate metal and sediments. Therefore, a National Pollutant Discharge Elimination System (NPDES) permit may be required if the EPA or State determines storm water discharge from a range contributes to a violation of a water quality standard or is a significant contributor of pollutants to the waters of the U.S.

Safe Drinking Water Act: The Safe Drinking Water Act of 1974 (amended in 1996), the primary law used to protect the nation's drinking water supply, sets drinking water standards that safeguard the public health against pollutants and contaminants.

7.1 Approach to Regulatory and End-User Acceptance

SACON bullet traps are being utilized as an advanced best management practice (BMP) on ranges that pose a significant risk for lead migration off the range. The SACON bullet trap both captures small-arms bullets and renders the bullet debris less mobile. Use of SACON provides the end user with a means to keep critical at-risk small arms ranges operational by enhancing compliance with the Munitions Rule requirement to localize lead to the range.

NEPA and Army Regulation (AR) 200-2 require environmental documentation for all federal actions (e.g., military training, new technology/equipment testing, construction projects, and real property transactions). Documentation of the SACON testing at ATC consisted of completing a record of environmental consideration prior to testing. No potential environmental impacts were identified and testing activities met the AR 200-2, A-12 requirements for categorical exclusion. The Federal and State regulatory community was not involved prior to or during the demonstration.

In analyzing the results of the demonstration, the most prominent regulatory issue associated with the full-scale implementation of SACON is the RCRA waste classification of SACON debris when it is removed from the range. The administrative, handling, and disposal actions required for the proper management of RCRA solid wastes are significantly less burdensome and costly than those associated with RCRA hazardous waste management. Thus, waste classification will impact the end-user's burden significantly. All weathered samples of SACON debris taken from the ranges indicate a solid waste classification. These findings ease the burden placed on planning for waste management and allow for initial operating procedures to be developed with generator's knowledge that the material removed will be nonhazardous. Waste samples at each range would need to be analyzed to support the nonhazardous classification at each location. A flow diagram (fig. 7-1) has been developed to aid the potential SACON user in determining process requirements associated with handling used SACON material. Local, State, and Federal regulations should be consulted in developing specific waste management procedures for individual sites.

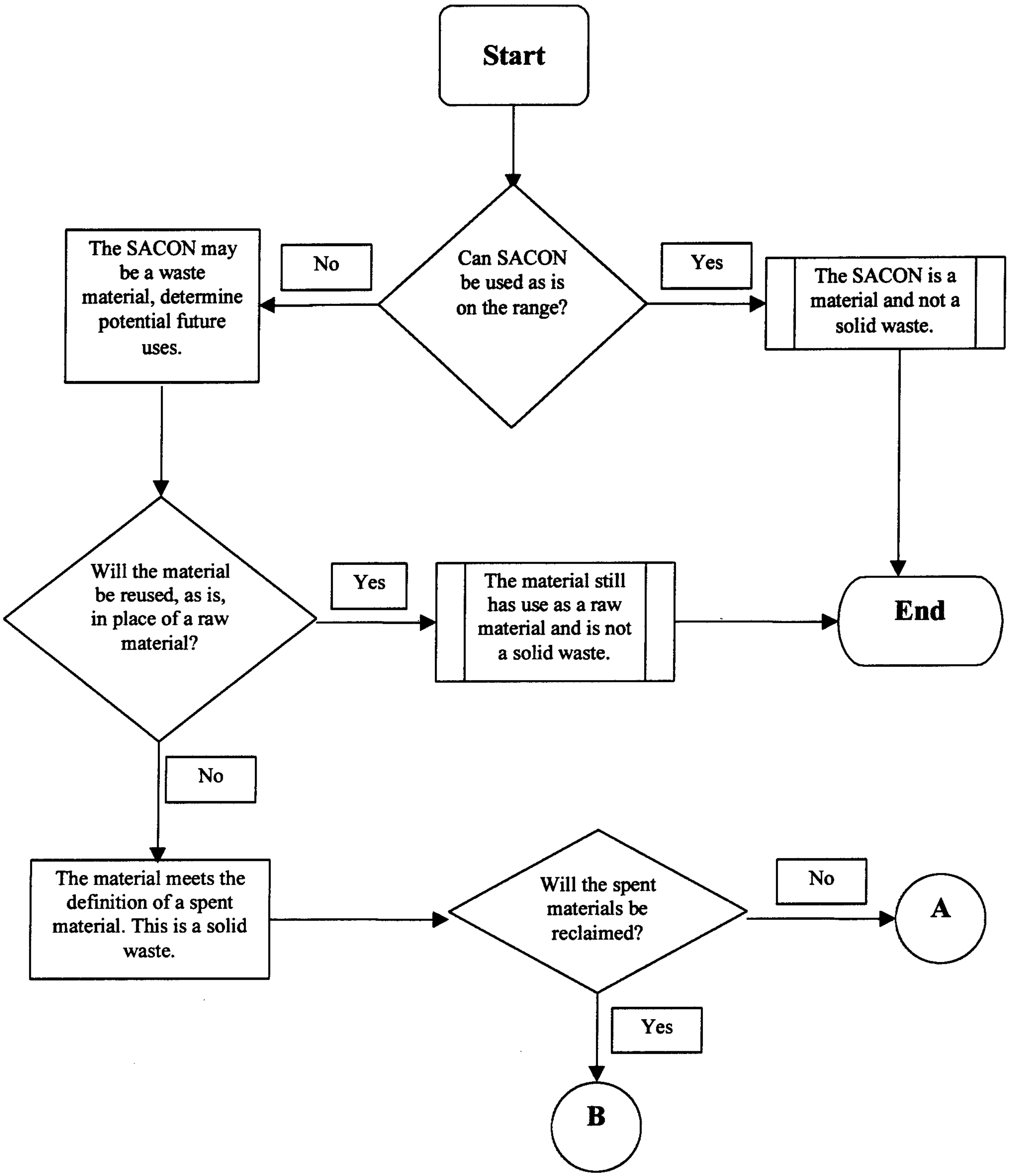


Figure 7-1. Flow diagram.

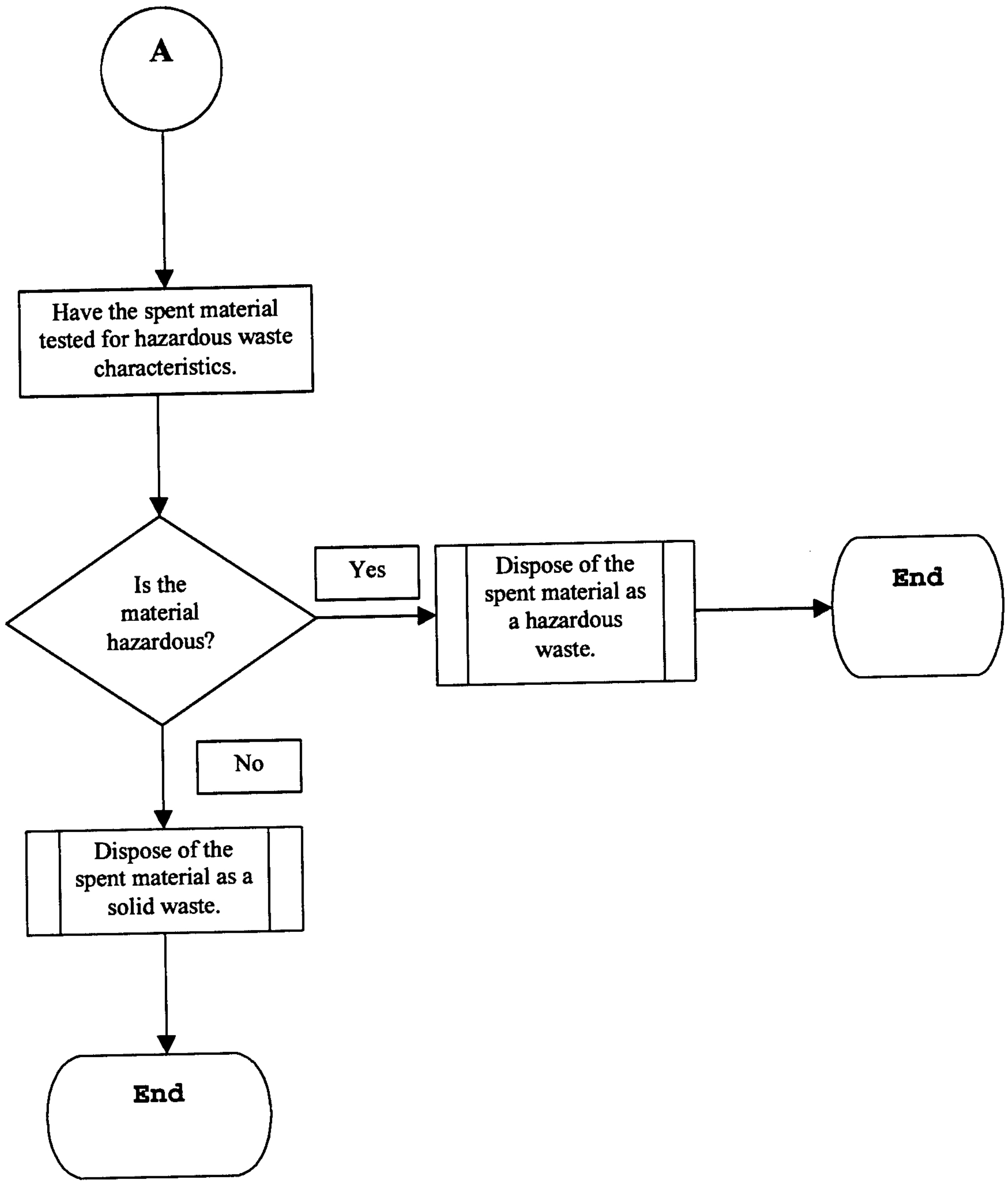


Figure 7-1 (Cont'd)

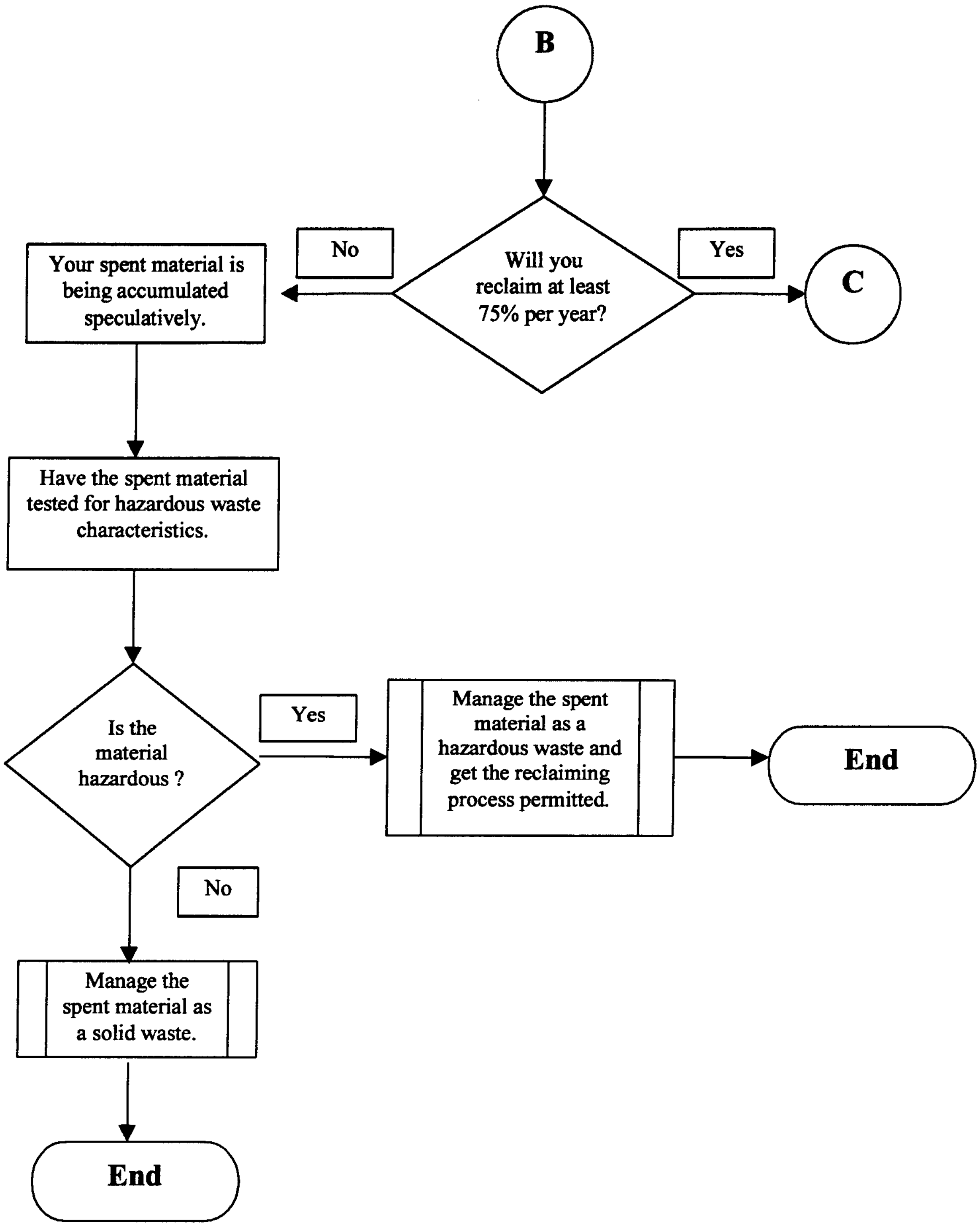


Figure 7-1 (Cont'd)

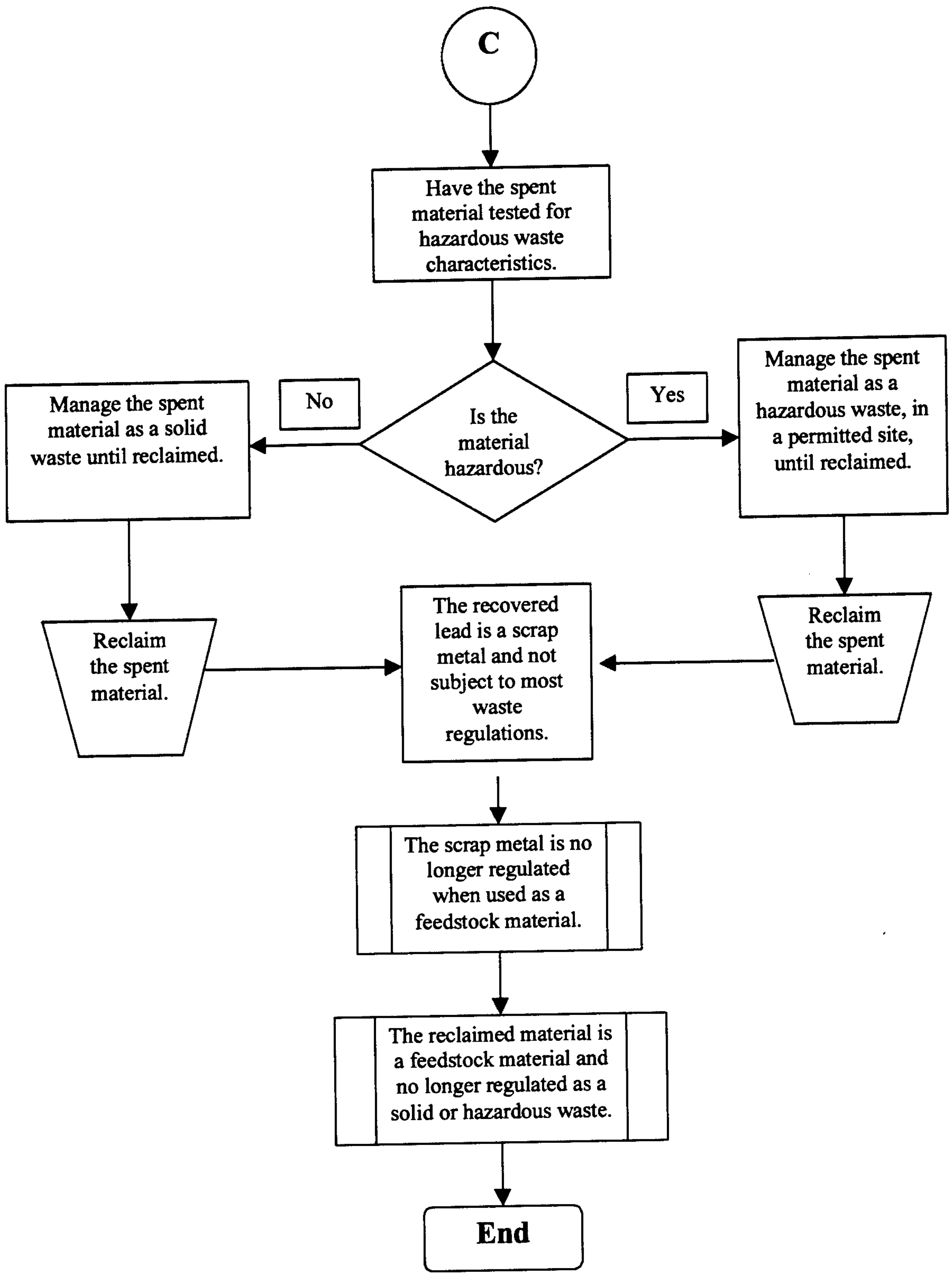


Figure 7-1 (Cont'd)

8. Stakeholder/End-User Issues

AEC initiated investigations of range user requirements with respect to bullet traps in 1996. A study was conducted to define user needs, develop evaluation criteria for bullet traps, and determine which general range types may benefit from the application of bullet-trapping technologies. The following installations were visited: Fort Hood, Fort Jackson, Fort Knox, Fort Benning, Fort Drum, Fort Pickett, Fort Sill, and Fort Leonard Wood. Based on subjective observations on various types of ranges and interviews with Range Managers and training personnel, bullet-trap design and performance objectives were developed which led to the establishment of suggested evaluation criteria for use in assessing a bullet trap's applicability to a specific range use. The resultant evaluation criteria were published in AEC Report No. SFIM-AEC-ET-CR-96142.

Concurrent with the development of the evaluation criteria, AEC conducted a comprehensive search for commercially available bullet traps to determine the types of traps currently available on the market. Using the developed evaluation criteria and the bullet-trap information gathered during the market search, AEC produced a preliminary assessment of the applicability of commercially available bullet traps to outdoor military small arms ranges. This feasibility assessment is documented in AEC Report No. SFIM-AEC-ET-CR-96195. This assessment was based solely on bullet-trap manufacturer's claims, which were mainly based on observed performance of the traps on indoor ranges. At that time, outdoor-range use of bullet traps that were capable of containing the bullet debris was almost nonexistent. SACON was identified as a potentially recyclable bullet-trapping medium with possible applications on the 25-Meter, AFF, ARF, and CPQC Ranges. The feasibility study provided projected results assuming range throughputs and trap performance.

Early in the ESTCP demonstration, WES initiated a joint study with the Department of Civil and Mechanical Engineering at USMA to investigate the use of SACON to gain performance data. WES provided references on their previous work with SACON to aid USMA in matching SACON with their needs to improve USMA's ARF Range (Range 5). The SACON design (block shapes), range integration, and Range 5 installation method were determined by two USMA cadets as part of Advanced Individual Study Course No. 489 (ref 36). With the funding of the ESTCP project, WES was able to manufacture and supply the necessary SACON materials to improve Range 5. On this range, the specific SACON tests that proved to be successful remain in use, providing target coffin protection and mitigating the impact erosion behind several of the targets.

USMA and Fort Knox were chosen based upon their desire to improve their ranges and the likelihood of producing the desired bullet throughput necessary to demonstrate the technology. Shaping of SACON materials and placement locations were determined by WES (except as noted on Range 5 at USMA above) with input from both Fort Knox and USMA range personnel. User input was solicited throughout the demonstration. A detailed data collection system was developed to capture the thoughts and opinions of the range users for the subjective and objective evaluation of the technology.

At the conclusion of the demonstration, the acceptance of the technology differed upon location and with use. USMA chose to continue the use of SACON on Range 5 (ARF) because of the reduced impact erosion achieved with its use. However, USMA chose to have the SACON barriers removed from Range 3 (25-Meter Range). The SACON installation on this range was perceived to be too labor intensive to warrant its use. Fort Knox chose to have all SACON removed from their ranges until a complete assessment of the material's costs, performance, and benefits could be completed. These factors, coupled with the current regulatory impacts on range use, would drive any future decision concerning the use of SACON or any other bullet-trapping technology on their ranges. Acceptance of the SACON bullet-trapping technology by range users was not fully received primarily because under the current regulatory environment, the no-action alternative of continuing current range operations exists and is more economical. The continued use of simulated SACON railroad ties on the ARF, AFF, and CPQC Ranges would require installation personnel to manufacture SACON. This is obviously more difficult than continuing to use landscape timbers. The use of SACON barriers to trap bullets on the 25-Meter Range again takes more range personnel labor than allowing the deposition onto the ranges or into existing berms.

Range Manager support for implementing bullet-trapping technologies will increase dramatically as the implementation of the Munitions Rule and increased regulatory scrutiny of range operations impact the ability of DOD to meet training requirements. Support for SACON will grow as costs are reduced and comparisons are made to the performance of other bullet-trapping technologies.

9. Technology Implementation

9.1 DOD Need

DOD operates approximately 1800 small-arms ranges. The number of these ranges that are "at-risk" ranges is unknown. "At-risk" ranges are those ranges where lead migration, through aerial, surface water, and/or groundwater transport, may result in regulatory action being taken that affects the use or operation of the range. USAEC subjectively estimates a subset of approximately 10 percent of the 1800 ranges are at risk of noncompliance with the Military Munitions Rule. SACON offers an effective method of reducing heavy-metal transport risk at these vulnerable ranges.

9.2 Transition

The demonstration objectives focused on identifying and validating the performance, cost, safety, logistics, training realism, and recycling aspects of the SACON bullet-trap material. The major findings of the demonstration are as follows:

- The SACON bullet-trap design tested contained 87 percent of the bullets fired at the trap. The majority of the released fraction of bullet debris was deposited immediately in front of the trap, forming a debris pile. Lead concentrations in the trap and debris pile exceeded 60,000 mg/kg.

- In the absence of weathering, the SACON debris samples collected at ATC exhibited TCLP levels that exceeded 5 mg/L, which would result in a hazardous waste classification based on lead toxicity. However, all samples taken from SACON bullet traps tested at Fort Knox and USMA that were exposed to the effects of weathering resulted in TCLP levels of less than 5 mg/L. Exposure of the bullet debris to the SACON material resulted in the formation of insoluble lead corrosion products. As a result, all SACON debris removed from these ranges was classified as nonhazardous and disposed of as a solid waste.

- Soil erosion resulting from repeated bullet impacts was reduced in front of and behind the target emplacements by burying SACON in these areas. Reducing soil erosion aids in mitigating the physical transport of lead debris from the bullet's impact point on the range. SACON also provides adequate protection of the target coffin when properly maintained. Mitigation of this impact erosion results in less-frequent maintenance requirements in these areas. An estimate of a two-thirds reduction in maintenance time for the areas where SACON was buried was subjectively made based on visual observations during the demonstrations. Free-standing SACON barriers did not perform as well due to rapid wear necessitating frequent maintenance.

- Durability testing in a 25-Meter Range application conducted at ATC indicated that a maintenance event will be required after 7,100 rounds are fired into the trap design that was tested.

- Nonrecurring costs associated with the installation of SACON bullet traps on a 25-Meter Range are estimated at approximately $1600 per lane. The annual recurring costs associated with the use of SACON, which consist of maintenance, waste management, and replacement SACON block manufacturing, were estimated at $3800 per lane. These recurring costs were derived based upon the assumption of an annual throughput of 30,000 M855 bullets on a lane and on the durability of the SACON bullet trap designs that were tested.

- Ricochet testing, conducted at ATC and assessed by the Corps of Engineers Engineering Support Center, proved that the use of SACON on small-arms ranges will have no effect on the range's SDZ.

- PPE will be required to perform maintenance on SACON barriers to limit lead and dust exposure.

- The weight of the SACON blocks used in the demonstration exceeded established limits for personnel lifting and handling to perform maintenance. Alternate block designs that utilize mechanical lifting and handling equipment must be used to safely install and maintain SACON bullet traps.

- A recycling demonstration conducted at WES resulted in the determination that SACON material that has been shot with the M855 5.56-mm round cannot be economically recycled using the process employed by WES. The process did not meet steel or lead reduction targets established for the demonstration. It should be noted that the applicability of these targets has since been questioned based on the field results of the live-fire testing conducted on the recycled SACON blocks. Further testing will be required to establish valid recycling performance criteria.

SACON does provide Range Managers with a means of effectively capturing and containing lead on small arms ranges, specifically in 25-Meter Range backstop applications and buried blocks to mitigate impact erosion around targets. SACON offers significant benefits in comparison to current COTS technologies. It exhibits an ability to inhibit the leaching of lead corrosion products. Other COTS bullet traps and soil berms do not have this lead stabilization capability. The waste generated from the normal range use of SACON did not exhibit hazardous waste characteristics and was disposed of as a solid waste. SACON is not flammable and can be formed in any shape, making it adaptable to more range applications than standard COTS technologies. However, like all bullet traps, SACON is an expensive means of mitigating the risk of lead transport from ranges and should only be considered as a last resort for keeping ranges environmentally compliant. Other methods of reducing lead transport risk should be investigated prior to installing any bullet-trap technology. New methods of stabilizing the lead on the range and mitigating physical lead transport in storm water runoff are being developed and may provide more cost-effective means of reducing lead transport risk and bioavailability.

Several shortcomings that were identified by the demonstration necessitate further development of the SACON technology. SACON is comparable in cost to rubber bullet-trap technologies when used on medium- to high-risk ranges with a low annual bullet throughput. Further development is required to reduce maintenance costs to levels comparable with the COTS technologies for use on ranges with moderate to high bullet throughput. This can be done through developing less labor-intensive maintenance practices and by increasing the durability of the SACON bullet trap designs. Development of larger, non-man portable blocks would increase reliance on mechanized material-handling equipment (MHE) but significant labor hours could be saved. In concert with the use of larger blocks, a method to patch the blocks in place would result in lower costs. This would reduce the volume of material requiring disposal to only the debris from the bullet cavities. Incorporation of the debris material as a feedstock to the patch mix would further reduce disposal volumes. Further testing should be conducted to enhance the durability of free-standing SACON objects placed on the ARF, AFF, and CPQ Ranges.

Preliminary plans have been developed to address the durability and maintenance issues identified above. SACON development and testing could be efficiently accomplished by an AEC/ATC/USMA/WES team with AEC providing program management and ATC serving as the principal investigating agency performing accelerated testing, coordinating field testing, and reporting. The Civil Engineering (CE) Department at USMA and WES would provide development and design work, to include refining SACON bullet-trap designs, investigating quick-setting patches, and implementing and improving operation and maintenance procedures. Field demonstrations would verify the performance of the newly developed procedures. Additional demonstration costs are estimated at $500,000. The timeframe for further SACON development will depend on the perceived need for the technology (which will be driven by increasing regulatory impacts on range use) and funding availability.

Industry has shown, and continues to show, an interest in the development and application of SACON. Ballistics Technology, Inc. (BTI) participated in the demonstration under a Cooperative Research and Development Agreement (CRADA). During the demonstration, WES and BTI collaborated on SACON designs and BTI conducted limited concurrent testing of the material in some range applications. BTI is currently marketing SACON for a number of range uses. Interest in the development and use of the material on ranges has also been expressed by Technical Consultants Group (TechCon) of Chattanooga, Tennessee, and others. Also, Terran Corporation, an environmental services firm, is currently working with the state of Ohio to develop SACON bullet-trap designs to address lead issues specific to the law enforcement ranges in Ohio.

At its current level of development, SACON is ready for application to small-arms ranges where the risk for lead migration from the range cannot be mitigated by existing erosion control methods. Implementation guidance is available in the form of a SACON Construction Manual authored by WES. The manual provides instructions for manufacturing and installing SACON for various range applications. The manual can be used to develop procurement specifications for specific range applications. It is available at the following World Wide Web address: http://aec-www.apgea.army.mil:8080. Technical assistance with the application and manufacture of SACON is also available via AEC's hotline (1-800-USA-3845) or e-mail: t2hotline@aec.apgea.army.mil and from WES by contacting Dr. Philip Malone at WES by phone, (601) 634-3960.

10. Lessons Learned

SACON technology has been in existence for years. The demonstration was intended to validate its application to small-arms ranges to capture bullets and control the dispersion of lead in the environment. The technology was innovative in that it provides a potentially recyclable bullet-trap material that reduces the ability of lead debris to leach into the environment. However, acceptance of this, or any technology designed to mitigate lead migration from small-arms ranges, will be limited until the impact from environmental regulatory directives is felt on range operations and troop readiness.

To a lesser extent, technology acceptance on small-arms ranges may be impacted by inconsistencies in the definition of user needs. The requirements for small-arms training and the methods of conducting training are well understood; however, the requirements for range upgrades, whether they are environmentally or operationally driven, are not clearly defined. A requirements document similar to an Operational Requirements Document (ORD) should be developed to ensure that range upgrades are completed in a manner which meets user needs. Further investigation into the modes of lead transport on ranges and the extent of the lead mobility issues on DOD small arms ranges is required to clearly define environmental performance targets for range upgrades. The formalization of requirements would enable the technology developers to better configure SACON or other lead mitigation technologies to user requirements. Creating a requirements document with performance specifications for user acceptance would allow environmental dollars to be leveraged to maximize environmental compliance and to simultaneously enhance training capabilities. Formalized and approved performance requirements will ensure the technology is implemented if those end-use acceptance criteria are met.

Other lessons learned pertain to the conduct of demonstrations on active small-arms ranges. If data collection requirements are lengthy or complex, complete and thorough data collection will suffer unless a member of the demonstration team is on site collecting. The data elements required to evaluate the SACON demonstration objectives were extensive. The burden for collecting the data was placed upon range personnel as additional duties. Creating additional work without clearly apparent gains to the range personnel leads to data collection shortcuts and oversights. If the data are critical (as they always are to provide an objective evaluation), appropriate personnel should be dedicated to the collection. Integrating the field data collectors into the demonstration team is a priority. Soliciting input from the user during data collection methodology development will enhance team building and result in improved data quality. During the development of data collection methodology, a clear and concise delineation of responsibilities must be made. Whenever possible, a data collector from the lead test organization should be on site throughout the demonstration period. On-site participation by the testing agency allows for real-time analysis of procedures and data and enables rapid correction to data deficiencies. Although this is a costly approach, the value gained through the conduct of the demonstration is diminished without accurate and complete data on which to base the assessment.

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APPENDIX B. DATA ARCHIVING AND DEMONSTRATION PLAN

Electronic copies of this report as well as a SACON implementation guidance (USAEC Report No. SFIM-AEC-ET-CR-99018) can be obtained at http://aec-www.apgea.army.mil: 8080 Copies of approved demonstration plans, reports, and/or data are available and can be obtained by contacting:

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Raw survey data have been stored on the Automated Test Incident Reporting System (ATIRS) maintained by the U.S. Army Aberdeen Test Center. For access to these data, contact the ATIRS administrator at www.atc.army.mil or contact:

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APPENDIX C. ABBREVIATIONS

AEC	=	U.S. Army Environmental Center
AFB	=	Air Force Base
AFF	=	automated field fire
ANEV	=	annual net equivalent value
APG	=	Aberdeen Proving Ground
AR	=	Army Regulation
ARF	=	automated record fire
ASTM	=	American Society for Testing Materials
ATC	=	U.S. Army Aberdeen Test Center
ATIRS	=	Automated Test Incident Reporting System
ATSC	=	U.S. Army Training Support Center
BMP	=	best management practice
BRAC	=	Base Realignment and Closure
BTI	=	Ballistics Technology, Inc.
CE	=	Corps of Engineers
CERCLA	=	Comprehensive Environmental Response, Compensation, and Liability Act
CFR	=	Code of Federal Regulations
COE	=	U.S. Army Corps of Engineers
COTS	=	commercial off-the-shelf
CPQC	=	Combat Pistol Qualification Course
CRADA	=	Cooperative Research and Development Agreement
CRBFT	=	composite rubber block friction trap
CWA	=	Clean Water Act
DCU	=	dust collection unit
DESA	=	Defense Evaluation Support Activity
DOD	=	Department of Defense
DPW	=	Department of Public Works
DRMO	=	Defense Reutilization and Marketing Office
ECAM	=	Environmental Cost Analysis Methodology
EDX	=	Energy Dispersion X-ray Spectroscopy
EPA	=	Environmental Protection Agency
EPCRA	=	Emergency Planning and Community Right-to-Know Act
ESC	=	Engineering and Support Center
FFCA	=	Federal Facility Compliance Act
FUDS	=	Formerly Used Defense Sites
GRFT	=	granular rubber friction trap
HUD	=	U.S. Housing and Urban Development
ICP	=	Inductively Coupled Plasma
JHA	=	Job Hazard Analysis
MHE	=	material-handling equipment
MIDAS	=	Munitions Items Disposition Action System
MOUT	=	Military Operations in Urban Terrain
MR	=	Munitions Rule
NEPA	=	National Environmental Policy Act

NPDES	=	National Pollutant Discharge Elimination System
O&M	=	operation and maintenance
OIC/NCOIC	=	officer in charge/noncommissioned officer in charge
ORD	=	Operational Requirements Document
OSHA	=	Occupational Safety and Health Administration
Pb	=	lead
PMCS	=	preventive maintenance checks and services
PPE	=	personnel protective equipment
RCRA	=	Resource Conservation and Recovery Act
REST	=	Range Evaluation Software Tool
RQ	=	reportable quantity
RR	=	Range Rule
SACON	=	shock-absorbing concrete
SAW	=	squad automatic weapon
SDT	=	steel deceleration trap
SDZ	=	safety danger zone
SOP	=	Standing Operating Procedure
TCLP	=	Toxic Characteristic Leaching Procedure
TechCon	=	Technical Consultants Group
TECOM	=	U.S. Army Test and Evaluation Command
TRADOC	=	U.S. Army Training and Doctrine Command
TWA	=	time-weighted average
USACE	=	U.S. Army Corps of Engineers
USEPA	=	U.S. Environmental Protection Agency
USMA	=	U.S. Military Academy
WES	=	Waterways Experiment Station